AMPUTATIONS

By

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John Hermans

Jan 1st 1935.

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Operative Technique—Formation and After-Treatment of the Stump from the Standpoint of Prosthesis

A Study Based on Seventeen Hundred Cases of Amputation for Injuries and Disease Occurring in the World War and Since Its Termination

By

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Published under the authority and with the approval of the Surgeon General, U. S. Army

To My Commanding Officer

COLONEL JAMES D. GLENNAN,

Medical Corps, U. S. A.

PREFACE

IN writing this monograph, an attempt has been made to express simply and briefly the results of the study of some seventeen hundred or more amputation cases which were under my care during the past four years. Amputation cases in the Army were centralized in certain general hospitals in this country and as all patients were required to be fitted with a proper prosthesis and instructed in its use prior to their discharge, the value of the various types of amputation and the functional value of the stumps obtained were clearly demonstrated.

It has been my privilege to operate on some seven hundred or more of these patients either in the form of primary amputations necessitated by disease, malignancy or trauma, or in the repair of the guillotine stump returned from overseas, or others impracticable from a prosthetic standpoint.

In all cases the apparatus was fitted in the orthopedic shops of those hospitals, which formed a part of the amputation service and were directly under the surgeon's charge.

As a result of this wealth of amputation material, new facts were established which proved that much of our technic in the past was wrong and that the surgery of amputations should be rewritten. The usual methods described in current textbooks on surgery will not give the amputé a stump with maximum function.

The surgeon in the past has too often contented himself with the healing of the suture line of the stump, having completed only the first part of his work so far as the patient is concerned.

Many excellent stumps from a surgical standpoint are spoiled because of the lack of proper after-care prior to the fitting of the prosthesis and because it has not been properly fitted.

This work treats of the general surgical principles of the amputation, the treatment of the soft parts and bone, the sites of election in all extremities, the after-cure of the stump, and its prosthesis.

The guillotine amputation popularized by the World War, so applicable in industrial traumatic surgery of peace time, is described along with the repair of the guillotine stump.

It is believed that the numerous illustrations will be of value to clarify the text.

No attempt has been made to include the history of amputations, to discuss theories, or to include old and discarded data not of a practical nature.

It is hoped that this short treatise will be of value as a ready reference to the young surgeon doing industrial surgery; to the student as a supplement to textbooks on surgery, and to the Medical Corps of the Army in the event of another war.

I wish to thank Brigadier General Walter D. McCaw, Medical Corps, U. S. Army; Lt. Colonel Percy L. Jones, M. C., U. S. Army, and Major James F. Coupal, M. C., U. S. A., for their kind assistance.

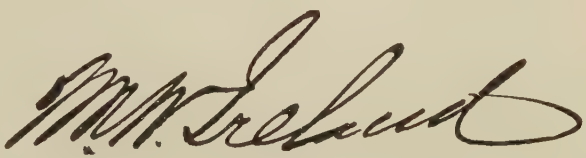
NORMAN THOMAS KIRK.

FOREWORD

THE experiences of the World War afforded an opportunity, unequalled in the past, for the study of the technique, results, and after-care of amputations.

The desirability of rehabilitating the wounded veteran served to emphasize the great need for the exercise of skill and surgical judgment in the performance of amputations and in the care of the stump in order that the results may be such that the individual will be enabled to take his proper place in the social and economic life of his community.

The author of this manual has drawn upon an extensive experience in this particular field, especially with regard to securing the proper functioning of an amputation stump, and it is believed that his discussion of the best methods of obtaining the desired results will fill a definite place in the field of war and industrial surgery and prove to be of great assistance to the surgeon engaged in this line of endeavor.



Surgeon General, U. S. Army

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Chapter I

GENERAL CONSIDERATIONS

Many new principles in the surgery of amputations, the treatment of the "stump" and its fitting were developed during the past war and the succeeding months of rehabilitation.

The total number of amputations done in the United States in a given year following industrial, railroad, and other accidents, and for disease, is very large, but the percentage of these treated until fitted with a prosthesis by any one surgeon is comparatively small.

The amputés in the military service were centralized in Army Hospitals and carried as patients until fitted with a suitable prosthesis. Every effort was made to return the patient to civil life at the earliest possible date with the maximum capacity to earn his livelihood.

In war the massive destruction of bone and soft parts of extremities by shell, early contamination and severe infection of devitalized tissues, as well as the unavoidable evacuation to the rear, presented very different problems in amputation surgery from those seen in civil life.

The severe shock which accompanied such injuries and which is also seen in industrial surgery following severe trauma necessitating amputation, requires the rapid removal of the useless extremity and the control of hemorrhage with the minimum increase in shock. To do primary amputations above the site of injury would not only greatly increase the mortality, but would leave those who survived with much shorter stumps and therefore less function. The guillotine operation is the one of choice.

The indications for amputation are many; no hard and fast

rules can be set down and one must rely on one's judgment. In traumatic surgery, immediate amputation is indicated only by uncontrollable hemmorrhage or where the circulation to the part is wholly destroyed, when the bone and soft parts, including nerve supply, are so hopelessly destroyed that recovery cannot be looked for. If there is a question of doubt, do a débridement, control hemorrhage, splint the fracture, dakinize, and await developments. If gangrene later develops or infection is so severe as to endanger life, amputate.

In sarcoma of long bones or malignancy in the soft parts, amputation is indicated through the joint above or through the bone above the joint which is uninvolved. Even this holds out little hope for a permanent cure of the disease.

The various types of gangrene due to arteriosclerosis or systemic disease such as diabetes, demand early amputation. Such cases, when the gangrene is in the lower extremity, usually show thrombosis of the main arterial supply of the entire leg, often extending well up into the superficial femoral. In such cases the tourniquet is not used when operating, as the blood supply of the flaps must be normal, which can only be determined by bleeding on section.

In gangrene from vasomotor disturbances following freezing or exposure, wait for a definite line of demarcation.

In deformities and ankylosed joints following injuries and infections in which function is fairly good without pain, amputation is not indicated. If a deformity cannot be corrected and the extremity is a hindrance to function, or if the pain experienced is so great that the patient cannot use the limb, amputation is indicated. An ankylosed ankle or foot, if at right angles with the leg and free from pain on use, is far better than the best artificial leg.

Amputation is the last resort in all cases and is the admission of the surgeon that he has failed or that he cannot restore function to the extremity.

FIG. 1.—AN IDEAL STUMP. Leg amputated through its middle third giving 7-inch stump by method described in text. The scar is barely visible just posterior to the bone end. Fig. 13 is the x-ray of the bones of this stump. Stump fitted with prosthesis five weeks after amputation.

An amputation is primarily performed to save life or to remove a useless extremity and when this is attained, it is our next aim to give the patient a serviceable stump.

The Ideal Stump (Figure 1) should possess the following qualifications: The length should be the maximum that can be given within certain limits. The bone end is covered by skin and subcutaneous tissue which is everywhere movable, snug enough not to crease or work into folds, free from sulci, redundancy, and sinuses, and presenting a linear scar. Muscle and fascia covering it are just enough to form a band of scar tissue over the bone end, adherent, not movable or redundant, and barely palpable. The X-ray shows the bone rounded off at the end, free from spurs or proliferation of any kind. The stump is painless and possesses no tender points or neuromata. It has free range of motion in all directions and is equal in power with the opposite member. It should not show edema, redness, or callus.

The ideal stump cannot always be obtained following the guillotine nor is it necessary. Excellent functional stumps are obtained which cannot be improved by surgery. If correction is attempted to give an ideal stump, so much bone shortening will be required that it may be rendered useless.

Stump length is the actual length of the stump and is obtained by measuring from the bone end of the stump to that group of muscles attached to its shaft which limit its insertion into the bucket of a prosthesis. These measurements are made as follows: In the leg, from the stump end to the insertion of the internal hamstrings; in the thigh, from the bone end to the crotch with the two thighs parallel; in the forearm, from the bone end to the insertion of the biceps tendon; and in the arm from the bone end to the anterior axillary fold. These measurements are useful and much more practical than

the bone length of the stump, as all fittings of the prosthesis are based on the former.

Extremities are roughly divided into thirds and stump lengths are ordinarily spoken of as lower, middle, and upper third.

Amputations can well be divided into two classes: (1) The closed method with suture of the soft parts at time of amputation, and (2) the open method or guillotine in which the extremity is removed and the wound left wide open. The conditions necessitating amputation make this classification useful.

1. *The closed method* is applicable when the amputation is one of election more or less and through healthy tissues where the soft parts are closed, primary union is expected, and the surgery of the stump is completed.

2. *The guillotine or open method,* amputating at the site of injury, is the method of choice in traumatic surgery in times of stress, in severe shock, and in the presence and for the control of infection. The extremity is removed and the whole cross section left exposed for dressing. Farther surgical treatment of the stump is necessary.

The closed method in detail.—The skin incision should be so fashioned as to give suitable flaps. The majority of textbooks teach that the flaps should be long, one and a half times the diameter of the extremity at the saw line, with bases equal in width to half the circumference. Various types of flaps as the circular, modified circular, oval, rectangular, anterior and posterior flaps, equal and unequal in length, the racket method and many others are well described and have a tendency to confuse rather than aid the surgeon.

All flaps in the past have been cut too long, contained too much muscle and were sewed up too loosely, probably because a certain amount of sepsis was expected to follow in the majority of cases and the shrinkage following this was anticipated.

The total skin flap length should not exceed the diameter of

the extremity at the saw line and should frequently be less as very little muscle is retained as will be shown later and the incision heals better if sewed under slight tension.

From a prosthetic standpoint the suture line should be ideally posteroterminal, just behind the bone end in the lower extremity and terminal in the upper extremity. To obtain this in the lower extremity the long anterior and short posterior flaps in the relation of two to one or three to two give the best results. If either flap be too long, the circulation to the skin may be poor causing the stump to be susceptible to delayed healing, ulceration and circulatory changes. In the upper extremity anterior and posterior skin flaps equal in length give the desired result. The bases of the flap in both instances are equal in width.

There are exceptions to this general rule which are stated with the indications in chapters two and three.

If bone length must be sacrificed, lessening the future functional use of the stump, any available skin present should be used allowing the suture line to fall where it will.

The saw line, then, is first determined, the skin flaps outlined and cut and their edges dissected free from all the underlying fascia to facilitate closure. The error of cutting the flaps a bit too long is better than having them too short.

They should always be trimmed if necessary to make a snug closure. The fascia is next cut, making the necessary flap to cover the stump end. Complete fascial closure is essential. It is inelastic and will not stretch as will skin, which fact must not be forgotten when flaps are cut.

Muscles.—The muscle in an amputation stump over bone end never again functions as muscle, but soon becomes converted into scar and fibrous tissue. A thick pillow-like pad of muscle, the preservation of which was almost universally taught in the past, should never

be used. It offers no advantages and soon becomes a large, hard, flabby, edematous, and usually tender mass, interfering with proper fitting and constantly becoming pinched and sore. The muscles must be anchored to the stump end, otherwise they will contract and the stump will become conical. This is best accomplished by cutting a thin muscle flap from one group, long enough to cover the bone end, and by cutting the remaining muscles circularly so that they will retract equally to the saw line. The muscle groups are then sutured to this muscle flap. This anchors them, giving equal muscular balance and along with the fascia forms a thin fibrous covering over the bone end, preventing the skin from becoming adherent.

Nerves.—Various methods have been described in the treatment of nerve ends to lessen the formation of neuroma and pain incident thereto. However, no method is entirely satisfactory. Bier covered the cut end of the nerve by a plastic operation on its sheath. Ritter removes a wedge shaped portion and sutures so that the neurillemma covered the axis cylinders. Bordenheur flexed the nerve on itself and sutured the end into a hole cut in the nerve sheath above.

All these are time-consuming and hardly applicable to the smaller nerves. The nerve cannot be shortened to its maximum by any of these methods.

The neuroma is formed by outgrowths of the axis cylinders which, meeting obstruction, turn and continue to grow, forming a bulbous enlargement consisting of nerve and scar tissue. This growth downward of the axis cylinder is a physiological process of repair and happens in all sectioned nerves to a greater or less extent. It has been shown experimentally that the injection of absolute alcohol above the point of section destroys the axis cylinders, thus preventing the formation of the neuroma. The neuroma per se may give no symptoms unless adherent to scar tissue or where so located that it is subject to trauma.

The sectioned nerve when not adherent to scar and lying above the stump end in its usual intermuscular septum produces no symptoms unless traction on the neuroma occurs from pull of adherent muscles.

A nerve trunk of any size usually contains a "bleeder" and if sectioned and allowed to contract into intermuscular septum, hemorrhage not infrequently occurs and is arrested with difficulty and not without trauma.

The results from the following method have proved more satisfactory: The muscle is retracted, the nerve is picked up and pulled down without too much traction, and injected with absolute alcohol. It is then ligated with number one plain gut to control hemorrhage and retain the alcohol, sectioned below the tie with a sharp knife, and allowed to retract. Painful neuroma sometimes follows this form of treatment and will from time to time require further operative treatment. There is no ideal method. The clinical results following the use of absolute alcohol have not been as successful as found experimentally.

Bone and Periosteum

Aperiosteal method (Figure 2).—The saw line should be so placed that the end of the bone will be parallel with and even for direct pressure on the end of the stump. The periosteum at the saw line is entirely cut through around the bone with a knife. The soft parts are retracted gently. If too strong traction is made, the muscular attachment to the periosteum will detach it from the bone and give rise to the formation of bony spurs. The bone is sawed through, care being taken not to splinter it. The periosteum is again cut through circularly to the bone using a knife a quarter of an inch above the sawed ends. This cuff of periosteum is then removed, care

FIG. 2.—Condition of bone end in thigh stump following aperiosteal amputation after six months use as end bearing stump. It is rounded off like the end of a broom handle. Note the absence of spurs.

being taken not to shred it and the end of the bone is rounded off with a rasp. Wash off the bone end and the soft parts with normal salt solution to remove all saw grafts, loose pieces of periosteum and bony spicules. If any are allowed to remain in the soft parts, they may live and proliferate causing pain, or they may act as foreign bodies. This method gives a bone end free from spurs, painless and as ideal for weight bearing as can be obtained. The endosteum is not disturbed, no bony spurs have been noted as outgrowths from it except following severe infection.

Musculo periosteal or osteoperiosteal method.—A covering is provided by this method for the amputated bone consisting of periosteum and the overlying muscle, raised as a single musculo periosteal covering and sutured over the bone end after amputation. To form this flap the deep muscle layer and periosteum is incised circularly half the diameter of the bone below the saw line and the periosteum is then detached with an elevator up to the saw line.

This method, although discarded by many surgeons before the war, is still described and recommended in many textbooks. It should be discarded as the results obtained by its use cannot be compared with those from the aperiosteal method and in addition it is time consuming, not applicable in the presence of infection and is basically wrong when the osteoblastic properties of periosteum are considered.

It was not used in the series of cases on which these findings are based.

Osteoplastic method.—This method aims to cover the amputated bone end by a bone flap having its periosteal connections and blood supply intact, with the idea of giving a painless, weight-bearing stump. The success of the amputation depends upon bone union and the absence of spurs or excess callus. It cannot be done in the presence of infection and is a failure if necrosis, non-union, absorption or tilting of the bone flap occurs. When successful, the stump has

no advantages over that obtained by the aperiosteal method. Examples of this method are Pirogoff's osteoplastic stump using a part of the os calcis and the Gritti Stokes transcondylar method in the femur using the patella. The latter gives an excellent stump.

Bone bleeding.—Control of bleeding from the bone should never be attempted by the use of bone wax or any other foreign substance as it invariably acts as a foreign body, causing suppuration and spoiling an otherwise excellent stump. Bleeding from the cortical bone is controlled by hammering the bone with mallet and chisel at the bleeding point. If the bleeding is from a good sized "spurter" in the cortical bone, it may be plugged with a piece of catgut that fits snugly into the hole. The rubbing of a piece of fat over cancellous bone or a small piece of muscle, cut free, macerated and applied with pressure, either to cancellous bone or the medullary canal, will practically always control bleeding.

Closure.—The muscle is closed first after the manner stated, using only plain gut. The fascia may be closed with the muscle but should preferably be closed separately. Complete fascial closure is essential and continuous suture is never used. The skin is closed with silkworm gut. Dermol may be used to give better approximation of epithelial border after the subcutaneous tissue and skin border have been approximated by silkworm. Exact approximation will save time in healing and also pain during dressings. Drainage is instituted using a roll of rubber tissue through and through under the fascia and muscle flap. Another drain is inserted under the skin. Drainage should never be placed over or near the bone end.

In closing, all layers must be sutured snugly, not tight enough to cause necrosis, but snug enough to take up all the slack in muscle and skin. If this is not done and dead space is left, bleeding is likely to occur with formation of a clot. The stump is dressed with sterile gauze, a snug, almost tight bandage applied and protected by a gauze

and cotton pad. Leg stumps should be splinted for ten days and all stumps are placed on pillows and elevated for one week to lessen edma and congestion.

The guillotine.—The operative technique of the flapless guillotine operation was described by M. F. Kelt in the British Surgical Journal, April, 1916, as follows: "The skin and deep fascia are divided usually in circular fashion, but sometimes more skin may be gained by making the incision oblique. After retraction has occurred, the muscles are divided at the level of the retracted skin, not too quickly so as to allow retraction of the layers, then the bone is sawed flush with the muscle, vessels are secured and nerves carefully shortened."

The above procedure must be followed in detail. Cut slowly through the muscular layers, allowing each layer to contract before the next is cut, otherwise a conical stump will result. It is well to tie muscle bleeders with suture to lessen the chances of slipping and double tie the larger vessels. Plain catgut only is used.

The periosteum at the saw line is incised with a knife, sawing through the bone at the cut edge. Care must be taken in retraction of muscles that the periosteum is not stripped from the bone and that no periosteum is shredded or left remaining in the soft parts. (Figure 3). A cuff of periosteum is not removed as the denuded bone becomes infected more easily and not infrequently sequestrates.

The flap guillotine method.—In this method, flaps of skin, fascia, and muscle are cut and everted, being held open by suture. The procedure is usually wasteful of bone length unless the flap can be obtained from the limb below the point at which the bone must be divided on account of injury. In the presence of severe infection, the flaps may slough or aid the infectious process by limiting drainage and soon become fixed in eversion by scar tissue. They interfere greatly with the proper after-treatment of traction. This method may

A B C

FIG. 3.—PATHOLOGY OF BONE IN GUILLOTINE STUMPS.

(A) Large terminal sequestrum, ring type involving all layers of the femur and two large lateral spurs resulting from the stripping of the periosteum from the shaft of the femur at the time of amputation.

(B) Large bony spur, the result of improper treatment of periosteum at time of amputation.

(C) Terminal sequestrum coming out from medulla and periosteal changes in lower end of femur showing presence of active infection.

be employed to advantage where the infectious process gives evidence of being mild, where the wound promises to become sterile at such an early period that secondary suture can be employed and where the patient will not have to be transported until healed.

The flapless guillotine became popular on the battle fields of France due to virulent, severe, and manifold infections, particularly by gas bacilli, following the traumatized and lacerated wounds caused by high explosives. Its advantages over the other methods of civil life, where flaps were cut and wounds sutured with invariable infections following evacuation, caused the Chief Surgeon of the American Expeditionary Forces to issue orders that no primary suture should be done following amputation and that by preference the flapless method should be used. This method had the following advantages:

1. It is the simplest method where time presses, and entails the minimum shock to the patient.

2. Patients become transportable earlier without the disastrous results which follow other methods and their active treatment can be carried out en route.

3. It gives the maximum bone length that can be obtained and offers less chance of bone infection.

Amputations in relation to the time performed following injury may be classified as primary or delayed. The primary is done immediately on receiving the patient at the front line hospital, the usual indications being an injury with extensive anatomical destruction and interference with blood supply to the part. A delayed amputation is done at the end of several days or weeks and its usual indication is infection or gangrene.

Site of amputation.—The site of the flapless guillotine is at the level of the lesion and should represent the maximum bone length that survived the injury. In a traumatic amputation a "débridement" only may be necessary.

In the delayed amputation for infection, the flapless method is performed at the lowest level necessary to save life after consideration of the extent of infection. It may be necessary at times to incise the tissues laterally to control infection above the stump end.

The following points should be remembered:

(1) The section should be at the lowest level, without regard to the ultimate utility of the part left.

(2) The operator should remember that a plastic of some kind must be done later and for that reason all joints possible must be saved, even though the stump will be useless. This will allow a re-amputation later through healthy tissues.

(3) An oblique guillotine can be done at times without sacrificing bone length and has advantages over the straight circular.

(4) A real guillotine division of a limb above a fracture is an extravagant procedure to be avoided when possible.

(5) A disarticulation at the knee joint, turning back the quadriceps tendon and skin when infection can be controlled, is far superior to a guillotine through the condyle. In the former the patient can later be given an end-bearing stump while in the latter, infection is introduced into the muscle of the thigh and healthy femur.

(6) No periosteum except that definitely adherent to bone in its entirety is left behind. A sub-periosteal amputation or disarticulation should never be done.

After treatment.—Immediately following a guillotine operation, if the soft parts are pulled down with the hands, the end forms an inverted cone with the bone end at the apex. Two days later after retraction of soft parts, the stump is conical with the bone forming the apex, and in a fleshy thigh, it protrudes four inches or more beyond the skin line. Skin traction, therefore, is applied within twenty-four hours after operation and continued until the wound heals. In the thigh, four strips of adhesive plaster two inches wide are applied to

the stump, extending from within two inches of the wound to the groin and held more firmly by circular strips. The ends are extended downward beyond the dressing and secured to a square block or circular iron ring to which is attached a rope which plays over a pulley on the bed end. Traction is applied by weights attached to the rope. The weight varies from ten to fifteen pounds, depending upon the amount required to gradually overcome the retraction of soft parts. In like manner, traction is applied to all guillotine stumps. The iron rings made of heavy wire or light iron about ten inches in diameter for the thigh will relieve the pull of the traction-straps on the dressings. Plain zinc-oxide adhesive works well; moleskin adhesive or one of the various forms of skin glue may be used with cotton or linen strips.

When the patient must be transferred, traction is maintained by fitting a Thomas splint or one of its modifications, and attaching the traction block to the end of the splint by means of a double cord, inserting a stick and tightening the cords to the desired amount on the Spanish windlass principle. The stump is supported in the splint by the ordinary muslin or flannel strips and is bandage firmly in place. The immobilization thus secured reduces pain to the minimum during transportation. Later when it is desired to make the patient ambulatory, it may be shortened by bending up the end of the splint so that the patient can walk about on crutches.

If proper and early traction is not applied, the stump becomes more conical, the muscle pull loosens the attached periosteum from the bone and opens up muscle planes, allowing infection to travel upward in the stump. As the wound attempts to heal, the scar tissue contracts down from above, shutting off the blood supply to the protruding bone now covered with unhealthy infected granulations, the bone frequently sequestrates and the wound does not heal com-

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FIG. 4.—THE GUILLOTINE AMPUTATION.

(A) Stump three weeks after flapless guillotine for gas gangrene—skin traction was applied on operating table.
(B) Stump practically healed six weeks after amputation, sterile ready for plastic closure. The scar is postero-terminal, showing results of skin traction.
(C) The same stump following plastic closure without bone shortening. Stump was rounded off normally six weeks after closure when fitted.

pletely, due to the insufficient blood supply. Further bone shortening will be necessary prior to closure.

If early traction is applied and kept continuous, unless the infection is severe and cannot be controlled, the soft parts are pulled down, the bone end early becomes covered with healthy granulations growing out from the endosteum and periosteum, and the unhealed area becomes smaller and smaller. At the end of four to six weeks, the wound may be healed with a posterior terminal scar and ample skin remains to do a plastic closure without bone shortening (Figure 4). Skin traction in addition limits to a minimum, joint contractures so frequently seen in the amputé not so treated and who has been bedridden or has held his stump in a fixed position to lessen pain.

Types of dressings.—Dakinization of the wound is begun on the operating table. The stump is covered with sufficient Carrel tubes so that every part of the wound is bathed hourly. The skin is protected by vaseline gauze, and the use of Dakin solution is continued until all sloughing in the wound ceases, granulation appears healthy, and infection is under control. A dichloramine-T dressing applied once daily may then be substituted.

The Carrel dressing technique should be rigidly carried out, with frequent bacteriological examinations to determine the type and severity of the infection.

Chapter II

AMPUTATION OF THE UPPER EXTREMITY

The stump of the arm or forearm is not subjected to as much wear and tear as is the stump of the thigh or leg. It is not brought into as constant use and the work done with it is far less. The amputé depends on his good arm and hand to perform most of his duties and uses the stump with its appliances, if he uses it at all, as a helper.

Almost any stump can be fitted with a working or cosmetic appliance. There are, however, certain stumps which are not satisfactory from a surgical standpoint, others that are fitted with difficulty, and some, owing to their length, do not give the maximum functional results.

The appliances for the forearm and arm cause pressure on, and are fitted snugly to, the lateral surfaces. There is no weight thrown on the end of the stump or pull upward on the skin, causing traction on the end. The scar is better terminal than lateral and the question of its being adherent is of little importance.

The guillotine stump in the arm or forearm treated with early traction heals with a terminal scar unless bone necrosis occurs and will frequently require no further operative treatment prior to fitting. The scar tissue will be dense and strong enough to stand any strain required of it. In the improperly treated guillotine with protruding bone and redundant skin with sulci, or where owing to excessive scar tissue the wound fails to heal, some form of a plastic closure is indicated. Bone shortening should never be done in the upper third of the forearm or above the lower third of the arm.

FIG. 5.—A thumb constructed from the first metacarpal, covered by its own skin after an amputation through the metacarpal phalangeal joint. It affords an opposing surface for the fingers.

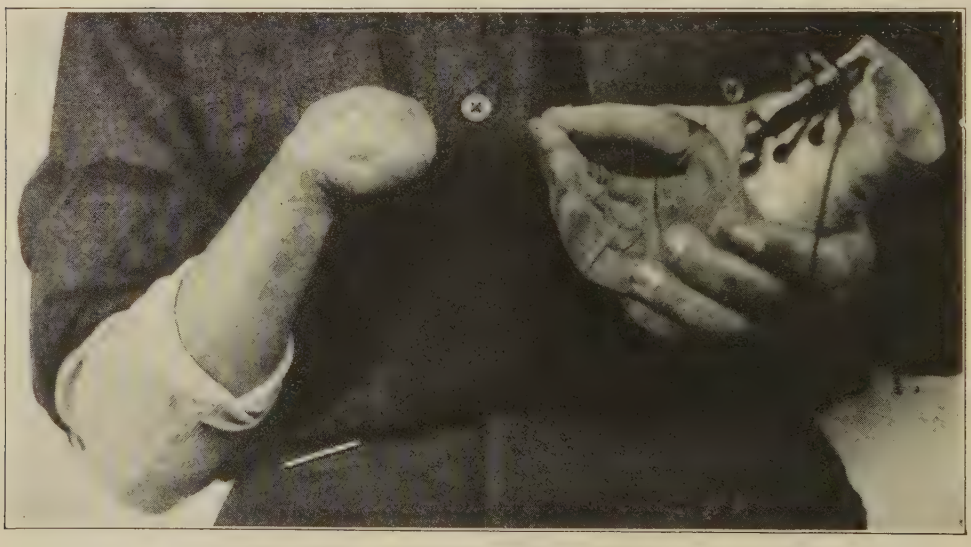


FIG. 6.—Amputation right hand with the carpus covered with healthy skin, normal motion at wrist. The patient holds in his other hand a cosmetic appliance. A prosthesis of leather attaching various types of working tools could be used with this stump to advantage.

HAND.—The presence of one or more digits with a fair range of movement, particularly if there is an opposing gripping surface, is better than any artificial appliance, providing the nerve supply of the skin is intact. An apposing surface for the remaining digit or digits may be built by some plastic procedure or an artificial one supplied (Figure 5).

Any plastic work using a flap from another part of the body, no matter how ingenious from a surgical standpoint, will be a failure if it lacks nerve supply. As soon as more or less constant pressure is brought to play, trophic changes occur, rendering it useless.

By means of heavy moulded leather with a cuff strapped to the wrist and forearm, a hook or some working tool may be added to a partially amputated hand thus increasing its functional value.

A stump made up of the carpus or metacarpus alone, if covered with skin and having a fair range or motion, is better than a forearm stump (Figure 6).

The appliance maker, however, prefers a forearm stump in that it is more easily fitted.

WRIST.—Disarticulation between the carpus and forearm gives a poor stump. Its contour is irregular, the styloid process of the radius and ulna are prominent and sensitive, the skin covering it is thin, tender, poorly nourished and easily traumatized, and when the artificial hand and working tool are fitted, the limb is longer than its fellow; also a more complicated fitting is required. Re-amputation at the junction of the lower and middle thirds of the forearm is advisable.

FOREARM.—The best stump is obtained at the junction of the lower and middle thirds of the forearm (Figure 7). In the lower third there is no muscular tissue covering the bones. The skin is thin, tender, usually cold and cyanotic. If the maximum of pronation is desired, however, the amputation should be done through the

FIG. 7.—Ideal length forearm stump, amputated through the upper part of the lower third of forearm.

FIG. 8.—Very short forearm stump. Length barely sufficient for fitting with prosthesis.

pronator quadratus muscle. In the upper third, if the stump is not one and a half inches or more in length, measured from the attachment of the biceps tendon, it is too short to operate an appliance (Figure 8). On flexion of the forearm, the biceps tendon will push the forearm bucket off the stump. Reamputation is indicated through the lower third of the arm in such a stump.

Great stress is laid by some on maintaining the pronation and supination in the forearm which may be lessened by the point at which amputation is done, lost through bony union of the two at the amputation site or by ossification of the interosseous membrane. This motion is never made use of in the temporary or permanent practical artificial appliance. We are not justified therefore in subjecting a patient to unnecessary operation or pain by treatment to preserve it.

The ideal forearm stump, as above stated, is obtained at the junction of the lower and middle third. The scar should be terminal, the two bones equal in length and covered after removal of one-fourth of an inch of periosteum, with a thin muscle flap. A small amount of muscle placed between the bone ends will lessen the chances of cross union. Equal skin and fascia flaps are used and blood drainage is established prior to closure. The interosseous membrane should not be disturbed above the saw line.

ARM.—Disarticulation at the elbow, if properly covered with healthy skin, gives a better stump than that at the wrist. It gives a large mass at the stump end in proportion to the rest of the arm and is more difficulty to fit than an amputation above the condyles. When fitted it will throw the new elbow joint lower than its fellow, though as a stump for work without an appliance, it has its advantages in being longer, larger, and more useful than an amputation higher up.

Lower third.—The best arm stump is obtained in the lower third. The saw line should be about an inch above the condyles and the supra-

FIG. 9.—An arm stump too short to be of functional value. It was fitted with a prosthesis for cosmetic reasons only.

condylar ridge should be removed. Any type of skin flap will answer. The scar should preferably be terminal. Enough muscle flap is used to give a thin pad about three-eighths of an inch in thickness to anchor the opposing muscle groups. The bone should be treated by the aperiosteal method. The nerves are injected with alcohol and shortened.

Middle third and upper third.—The maximum bone length should always *be saved* in this region at the primary operation. It should never be shortened later unless diseased. A stump above the middle of the arm is of little or no value from a working standpoint, being too short to give the necessary leverage (Figure 9). The stump of the upper third may be "lengthened" and improved for the fitting of a cosmetic appliance by doing a tenotomy of the pectoralis major in the anterior, and the teres major, and latissimus dorsi in the posterior axillary fold. This gives actual increase in stump length insofar as the fitting of the appliance is concerned and increases the range of motion.

SHOULDER.—Amputation through the humerus below the axillary folds is more desirable than disarticulation when all diseased tissue can be removed and when infection can be controlled. It occasions less shock to the patient at operation, there is less atrophy of the muscles of the shoulder girdle and less nerve pain after healing. The post guillotine disarticulation usually requires plastic removal of scar tissue and of tender nerve bulbs which are adherent.

Painful and tender stumps with neuroma are far more frequent and persistent in the arm than in the forearm, leg, or thigh in the order enumerated, regardless of the treatment of the nerve at the time of section. In the forearm definite neuromata when present are found on the ulna and radial nerves, pressure causing pain referred to their corresponding distribution in the amputated hand. The pain is worse in those cases where the neuroma is adherent to the

scar tissue. The same conditions are found in the arm, more particularly in the upper third, and in the disarticulated shoulder. Practically none of the latter cases are free from pain of some degree, usually referred to the amputated arm even though the axilla has been cleaned of scar tissues, all nerves dissected out, injected with alcohol, shortened, dropped back and covered with a pad of muscle or fat. This can probably be explained in part by the fact that in the forearm, and more especially in the upper third of the arm, the large nerve trunks are very superficial, being covered only with skin and fascia, and are therefore more subject to trauma. Frequently after proper removal of the neuroma, the pain subsides for good; again, the neuroma reoccurs where last sectioned and the symtoms return as before.

X-ray examination should be made to rule out diseased bone; reoperation should not be advised for at least a six months' period during which time the pain may subside. An exploratory operation often fails to show any pathological condition. This pain not infrequently is a neuritis, or a posterior reticulitis and is not due to a painful neuroma.

Kineplastic amputation.—Vanghetti, an Italian surgeon, was the first to do this work and publish his findings. He observed that if the distal portion of the muscle or tendon be freed from its insertion and covered with skin, the muscle retains its voluntary power of contraction. Skin-lined apertures by ingenious plastic methods are made through muscles or tendons such as biceps, triceps, or some flexor or extensor group. A ring is fitted through this canal, a weight is attached by means of a cord, and the patient is instructed to lift the weight, exercising the muscle groups by voluntary contraction. The amount of pull the patient can exert is often comparatively great, but the excursion occasioned by the contraction is small. By means

of cords from the ring through the muscle flap, the artificial arm and hand are worked by muscular contraction.

This work is constructive, but its future depends upon the development of a practical, simple prosthesis using a relatively strong pull with a short excursion that will be functionally useful.

Chapter III

AMPUTATION OF THE LOWER EXTREMITY

The function of the stump of the lower extremity is to carry the body weight in whole or in part and to act as a lever to produce locomotion in walking. The work required, therefore, differs from the upper extremity and necessitates different basic principles.

Ideally, the stump should bear the whole body weight on its end as nature so constructed the long bones to function. This, however, is seldom obtained to the full degree. Partial end bearing is frequently obtained. There is always more or less pull upward on the soft parts in a properly fitted appliance, causing tension over the bone end. Dense adherent scar tissue will seldom stand the strain and healthy, non-adherent skin is essential.

The Toes.—A plantar flap is used when a toe is amputated. A single toe should never be left unless it is the great toe, as it will become deformed and painful, and renders a proper fitting difficult or impossible.

Metatarsus and Tarsus.—A stump in which the head of either the first or fifth metatarsus has been removed is a poor one as the anterior points of the weight bearing tripod are lost. When the heads of these bones are insufficiently covered with thin skin or scar tissue the stump is poor.

In amputations through the metatarsus, a long plantar flap is used.

Until the middle third of the leg is reached, any amputation posterior to the base of the metatarsal bones to which are attached the peronei and tibialis anticus and posticus muscles should be done only as a temporary measure. In other words, it is believed that an

FIG. 10.—The unsatisfactory Chopart amputation. A tenotomy of the tendo-Achilles was done and patient tried to use the stump with suitable prosthesis for six months without success and the deformity recurred. The leg was later amputated through the middle third of the leg giving an ideal stump with 100% function.

ideal stump obtained by the closed method through the middle third of the leg, is the best stump that can be given an amputé, unless the muscular attachments cited above, at the base of the metatarsi, can be preserved.

Lisfranc used a long plantar and short dorsal flap and disarticulated at the tarsometatarsal joint.

Chopart used the same type of flaps, disarticulating at the midtarsal joint (Figure 10).

In both methods, the opposing tendons are sutured or the extensors are sutured to the dorsal periosteum. If proper muscular balance could be obtained by these methods, these stumps would be functionally good with proper fitting appliances.

The end result seen in war wounds, the majority of which it is true were following the guillotine, was invariably poor. The stump was always found in plantar flexion due to the unopposed or weakly opposed pull of the tendo Achillis and was invariably inverted. The weight when it could be borne, was thrown on the outer margin of the foot and particularly on the outer corner of the stump, causing pain. Tenotomy of the tendo Achillis gave some relief for a time but the deformity recurred.

The ideal stump with equal muscular pull is difficult to fit. The appliance has no ankle motion and requires a stiff metal brace fitted either over the tender shin bone in front or encasing the calf muscles behind three-fourths of the distance to the knee with a leather cuff lacing either behind or in front holding it in place. Pressure occurs on the tender malleoli causing pain.

The Leg: *Lower third.*—The following are types of operations done in or near the ankle joint:

1. Osteoplastic (Pirogoff).
2. Symes method.
3. Other amputations.

The success of the Pirogoff amputation depends on bony union. The operation should never be done in the presence of infected tissue. It is painful and useless if bony union fails. It gives a poor stump from a prosthetic standpoint, in that it is too long and when properly fitted to give ankle motion, the limb is longer than its fellow. It has the advantage of allowing direct weight bearing for a limited distance in an emergency without an appliance.

Huggins states that "A Symes stump which is not entirely end-bearing is inferior for functional purposes to an amputation through the leg." He enumerates some four or five reasons for failure and states that unsatisfactory stumps are not uncommon.

The observation of the stumps of cases returning from overseas treated by this method gives the same findings except that they must all be classified as unsatisfactory if the above quotation is to be taken literally, as none could take entire end-bearing. The large majority were reamputated through the middle third of the leg.

The stump is fitted with a heavy leather laced boot extending to the knee, which must fit snugly throughout or friction with pain and laceration of skin occurs. The metal uprights in the leather are unyielding and are painful over what is left of the malleoli. The lateral bearing reinforces the end bearing and takes some of the weight. Fitting, taking additional weight off the end, was attempted by throwing it over the upper end of the appliance around the bony parts of the tuberosity and head of the tibia as in the ordinary below the knee stump. This stump was never found as satisfactory as the amputation through the middle third.

Amputations anywhere through the lower third of the leg are unsatisfactory. The tibia is small at this point, covered only with tendons. The skin lacks subcutaneous tissue, is thin, poorly nourished, heals slowly, if at all, and is usually cyanotic. The stump is so long that it interferes with the ankle motion in the standard set-up

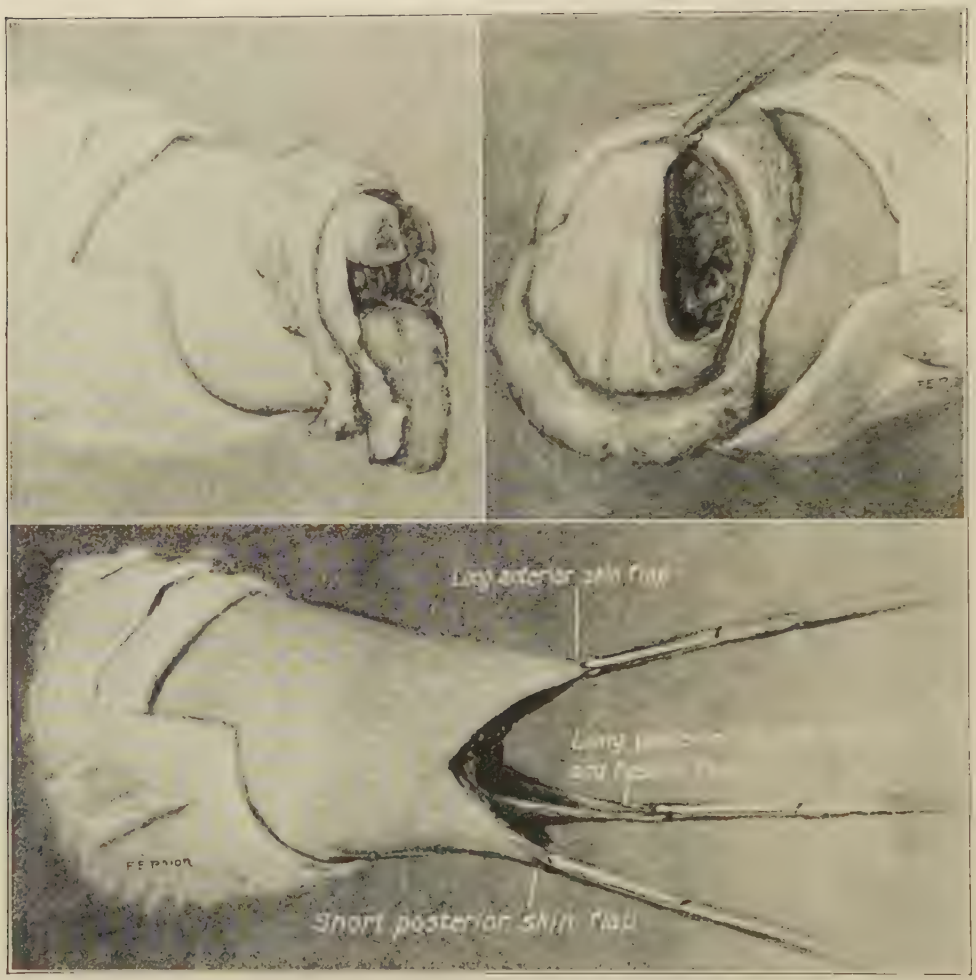


FIG. 11.—DIAGRAM OF AMPUTATION THROUGH MIDDLE THIRD OF LEG

(A) Anterior and posterior skin flap turned back, tibia sawed through and crest bevelled; fibula shorter than tibia, long posterior muscle flap. Fascia and muscle between tibia and fibula has been cut at saw line.

(B) Flaps pulled down by forceps to show relative length and position.

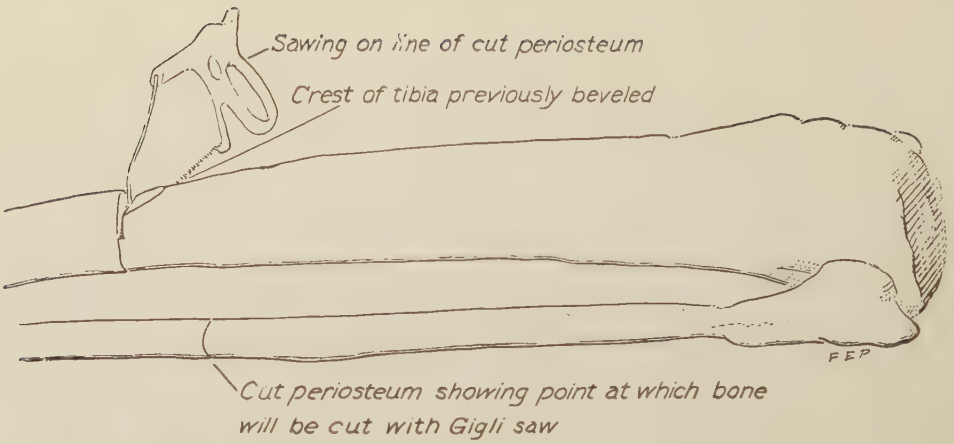
(C) Posterior muscle fascia flap pulled up over stump end, apex covering bevelled crest of tibia, inner margin in contact with inner surface of tibia and outer margin ready for suture to muscle and fascia between tibia and fibula. A rubber tissue drain is inserted under this flap.

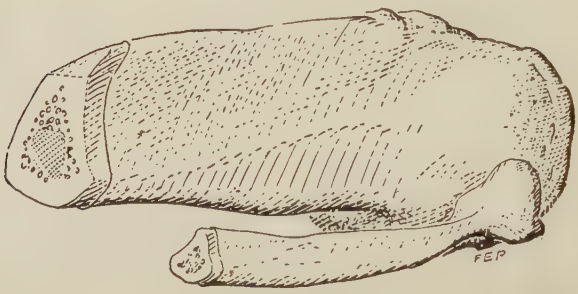
and is therefore more difficult to fit. It possesses no advantages due to its additional length.

The middle third.—This point gives the ideal stump (Figure 1). The stump should not be less than five and one-half inches or more than seven and one-half inches in length in a man of average height. All measurements are made from the internal hamstring to the bone end with the knee flexed at right angles.

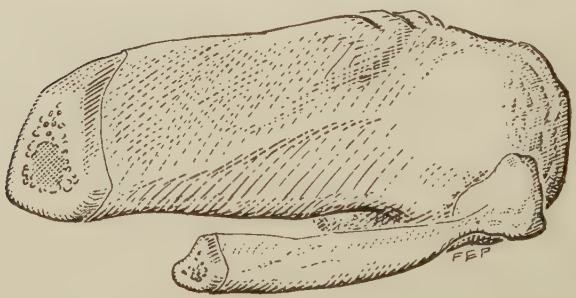
Operation (Figure 11).—Determine the saw line, cut a long anterior skin flap and a short posterior one in relation of two to one. Dissect the skin flap back to the saw line. The fascia between the anterior border of the tibia and the fibula is cut on a line with the saw line, and the anterior tibial group of muscles between the tibia and the fibula is now cut so that they will retract to the level of the sectioned fascia. Introduce a thin-bladed amputation knife behind and in contact with the tibia and fibula, cut downward and backward through muscle, tendon and fascia. This will form a long posterior muscle-tendon-fascia flap, triangular in shape, to cover the stump end. With a knife cut through the periosteum circularly around the tibia at the saw line, and outline the saw line to be used for bevelling the crest of the tibia. The muscle is cut back from the fibula, care being taken to detach no periosteum so that it may be sectioned one inch or more above the saw line of the tibia. Cut its periosteum circularly with a knife. With an amputating saw bevel the tibial crest along the incised periosteum and saw through the tibia at the saw line. With a Gigli saw cut through the fibula. Remove a cuff of periosteum one-quarter of an inch deep from the end of the tibia, its bevelled crest, and the fibula, and with a rasp round off the sharp corners of bone. Sharp bone cutting forceps are used to better advantage on the fibula (Figures 12 and 13).

Excess muscle is cut away from the long posterior muscle flap so it will not be more than a quarter of an inch thick at its base,





After removal of 1/4 inch cuff of periosteum



After removal of sharp corners with rasp.

FIG. 12.—Diagram representing the various steps in the treatment of the bone and periosteum in an amputation through the middle third of the leg. FIGS. B and C are foreshortened to show the bone end better. The endosteum is not disturbed.

FIG. 13.—Aperiosteal amputation at point of election in the leg, giving a 7-inch stump. Note absence of periosteal proliferation spurs. The fibula is a good inch shorter than the tibia and the crest of the tibia is bevelled.

tapering down to tendon and fascia only at its apex. It is then brought up over the stump end and any excess is trimmed away. The vessels are secured and ligated, the anterior and posterior tibials and the musculocutaneus nerves are isolated, pulled down, ligated, injected with absolute alcohol, and sectioned. The latter nerve runs parallel to the fibula along the deep fascia and when not properly shortened forms a neuroma in the region of the fibular end, which, when compressed against it, causes pain. The tourniquet is removed, all bleeding arrested, the muscle flap is brought up from behind under tension, sutured externally to the fascia and anterior tibial group of muscles between the tibia and fibula, the inner border is sutured to the periosteum on the inner surface of the tibia, and the tip of the triangular flap is secured above the bevelled crest of the tibia covering it. The skin flaps after any reshaping that is necessary, are closed with interrupted silkworm stitches. A rubber tissue drain is introduced from the corner of the wound underneath the muscle flap.

The stump is tightly bandaged after applying a sterile gauze dressing and is splinted in extension. It is dressed at the end of forty-eight hours when the drain is removed.

This technique gives an ideal stump with the scar just posterior to the end of the tibia without redundant soft parts, ideal in length, with freely movable skin and partial end bearing.

Modification of muscle and fascial flap.—In the upper or middle third when the patient has a large calf muscle, another procedure may be used giving equally good results. Lateral flaps of fascia are cut so that they can be sutured over the stump end. The calf muscles are divided at an engle so that posteriorly they will be shorter than at the saw line. The tibialis anticus muscle is cut long and divided longitudinally, the inner half being removed. The remainder of this muscle is sutured across the bevelled crest and end of the tibia. The

end of the fibula is covered and the fascia sutured, drainage is established and the skin closed.

The muscle-suture over the bone end is not done primarily to give muscle balance and new attachment, but to cover the end with what will become a thin pad of fibrous tissue to relieve direct bone pressure on the skin. Such stumps will be partially end-bearing. The muscles in the leg stump atrophy early, differing from those in the thigh in that they never again function as muscle.

The fibula must always be shorter than the tibia, otherwise end-bearing is impossible and the stump is usually painful even in cone bearing. Any pressure exerted on its end pulls on the interosseous membrane and may cause a subluxation of the poorly constructed joint above, thereby causing the head of the fibula to become more prominent. The interosseous membrane above the saw line should not be traumatized.

The crest of the tibia.—The tibia is more or less triangular on section, the apex being formed by the crest of the bone. If this is not removed, it remains as a sharp point over which the skin is drawn. After the stump is fitted or frequently before, due to the pressure brought to bear on this sharp point against the skin, thickening, redness, or ulceration may occur. The bucket on every step the amputé takes causes pressure and pain.

At amputation the crest must always be bevelled. With a saw, cut it away, beginning one-half inch above the cut end of the tibia and coming through the cut surface a quarter of an inch behind the tip of the crest.

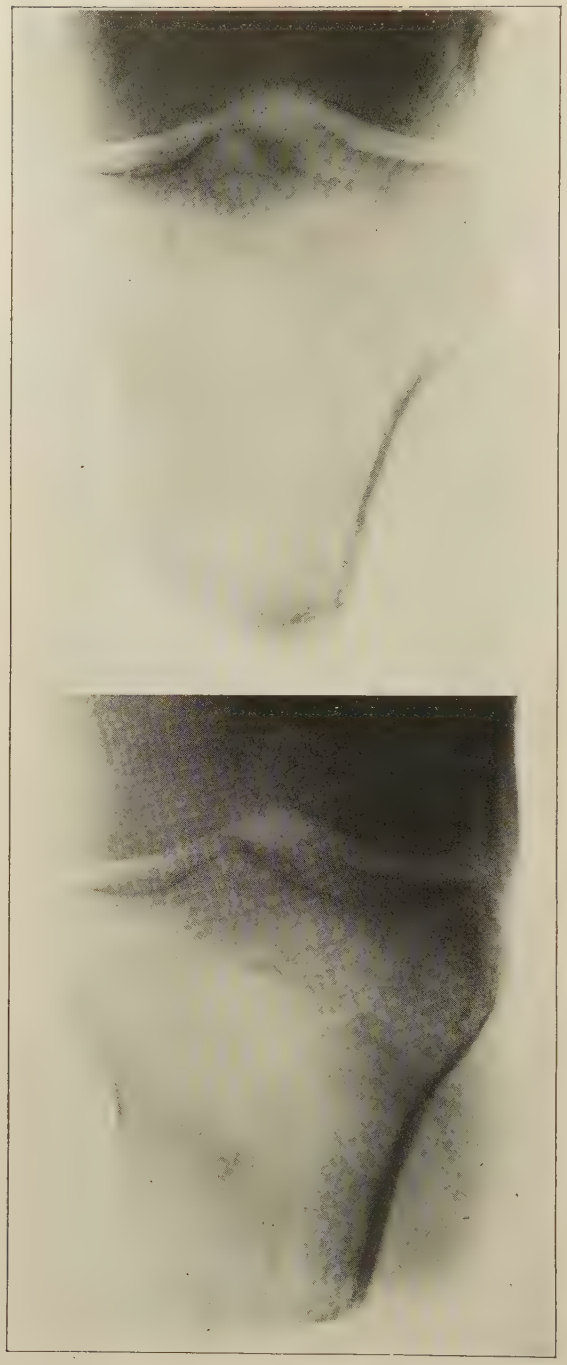
The bevelling is easier before sawing through the tibia. The three remaining sharp points are rounded off with a rasp. The periosteum is removed around the bevelled crest with as much, if not more, care than at the bone end.

FIG. 14.—A short below knee stump following the repair of a guillotine after the removal of the head of the fibula. FIG. 15 is the x-ray of this stump. This patient had excellent function after fitting of prosthesis.

The upper third (Figure 14).—All bone length must be conserved in the stump less than five and one-half inches long. Skin flaps should not be fashioned, but all available skin must be used. When the stump is flexed at right angles to the thigh, unless two fingers can be placed side by side on its posterior surface, below the internal hamstring tendons, it is too short for use in a leg bucket. This length must represent bone length. In a stump appreciably shorter than this reamputation is indicated above the condyle of the femur.

The amputation at the "site of election" as described in text books should never be done if longer bone length is possible. The site was selected in the days of the peg leg so that the amputé could either walk well on a flexed knee peg or after a fashion in a below-knee bucket.

Tenderness over the fibula.—The head of the fibula is tender when pressure is applied. No two have the same conformation or exact location and some are very prominent regardless of the stump length. In the short stump, the end of the fibula often protrudes at an angle and the soft parts over it are sensitive, easily traumatized, and frequently become ulcerated. Luxation in the joint at times occurs and the head becomes movable. Division of the external popliteal nerve will not give relief, but the condition can be improved by hollowing out the bucket as is required in the prominent head of a longer stump. The fitting of such stumps is difficult and requires constant attention and readjustment. The head and what remains of the shaft of the fibula should always be removed in such a case and the external popliteal nerve shortened. This is never done subperiosteally. The head of the fibula is removed in all leg stumps which will have a bone length of three inches or less. Its removal will aid materially in obtaining additional skin for plastic closure in a short guillotine stump (Figure 15). By its removal a poor stump is made an excel-



(A) Short below knee stump following guillotine. Note irregularity of tibial end and very prominent fibular head and remaining shaft, which will interfere with prosthesis and cause pressure sores on skin covering it.

(B) Same stump after rounding off of tibia and removal of fibula. Note larger area of bone surface bearing.

FIG. 15.

lent one for fitting, removing all painful and tender points. Stumps in the upper third should ideally always be partially end-bearing.

Any leg stump with an ankylosed knee or in which motion is markedly limited, is useless and should be reamputated through the lower third of the thigh.

THE THIGH.—The end bearing stump is the ideal stump and can be obtained in the lower and occasionally in the middle third of the thigh. In amputations above this level, the ischial and cone bearing fitting gives better functional results using the stump as a lever only. Stump length is measured from the perineum to the bone end, the thigh being parallel to its fellow.

Amputations through the knee. Disarticulation.—The condyles afford a poor weight bearing surface being unequal in length, irregular in contour and usually tender even when covered with healthy skin. The amount of skin required to cover it is large. Covered with scar tissue it is useless. It is difficult to fit and the cosmetic effect is not good. It should never be selected as an operation of choice.

The ideal thigh end-bearing stump is obtained by amputation through the cancellous bone of the condyles. Either an osteoplastic or tendoplastic method may be used. The latter is preferable and will be described in detail.

Osteoplastic methods.—Ssabanejeff's transcondyloid femorotibial method requires healthy tissue below the knee almost if not actually long enough for a good leg stump, a non-fixed patella and ideal aseptic conditions, as the greater part of the synovial membrane of the knee is retained, and its success depends upon bony union. The operative procedure is well described by Lyle. The end results give a stump stronger than the opposite thigh, bulbous on the end and difficult to fit.

The Stokes-Gritti method depends upon bony union between the patella after the articular surface has been removed, and the femur

sectioned above the condyles. It gives an excellent end-bearing stump, supporting the whole body weight when successful. The possibility of delayed union, tilting of fragments, absorption infection with necrosis, and spur formation, must all be considered.

The supracondyloid tendoplastic method.—The following method gives an ideal end-bearing stump, ready for fitting in five or six weeks after amputation. The contour is symmetrical, scar posterior, bone free from spurs, painless, and covered with sufficient soft parts. It gives a length that is easily fitted with an appliance so that it will not be longer than its fellow and yet does not sacrifice stump length from a functional standpoint (Figure 19).

A large anterior flap of skin, fascia, and quadriceps tendon is cut. The skin, fascia and muscles posteriorly and on the sides behind the flap are divided circularly to the bone. The saw line is supracondylar through cancellous bone, while the bone is still triangular in shape. The saw line will be determined by length of the quadriceps tendon which must cover it. The tendon is sutured behind and laterally to the fascia.

Operation (Figure 20).—The anterior skin flap base upward is begun at the saw line laterally, corresponding with the mid-long axis of the femur, extends downward, curving across the upper third of the patella to the opposite side of the thigh and back to a point corresponding to the starting point. The incision through the skin is then carried circularly around the posterior surface of the thigh connecting the above points.

The anterior skin flap is freed from the underlying fascia to the depth of three-quarters of an inch around its border. The quadriceps tendon is then cut free from the patella, as close to it as possible, the fascia and muscular tissue joining the tendon laterally are incised along the border of the contracted skin of the anterior flap to its base. This flap of skin, tendon, and fascia is then raised and

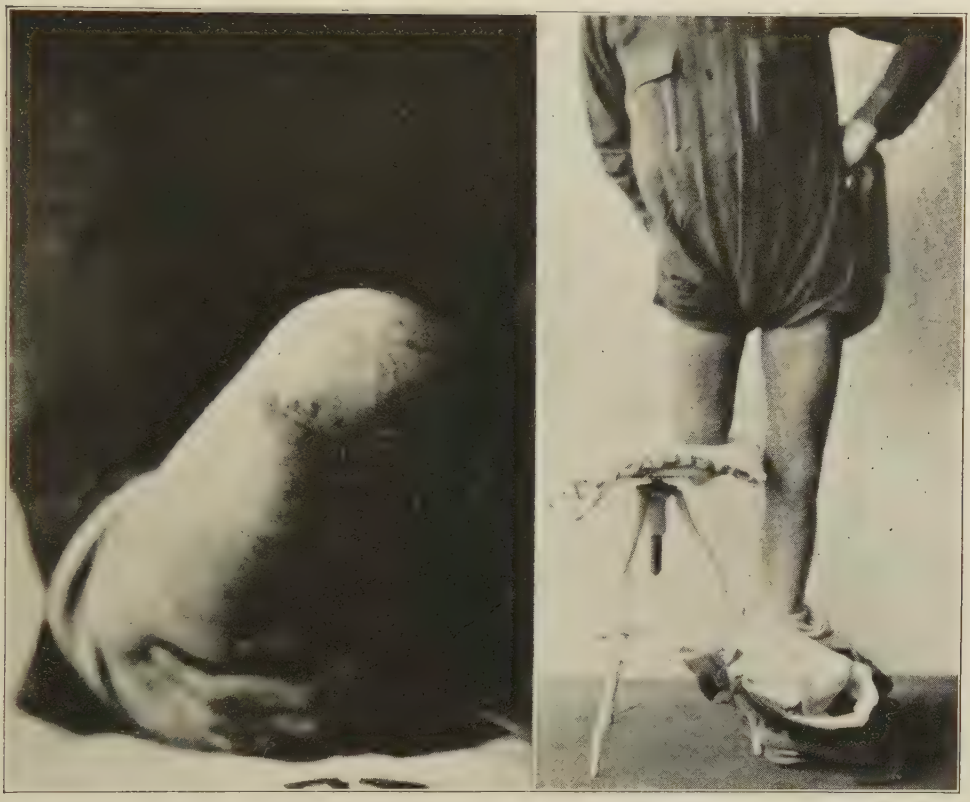
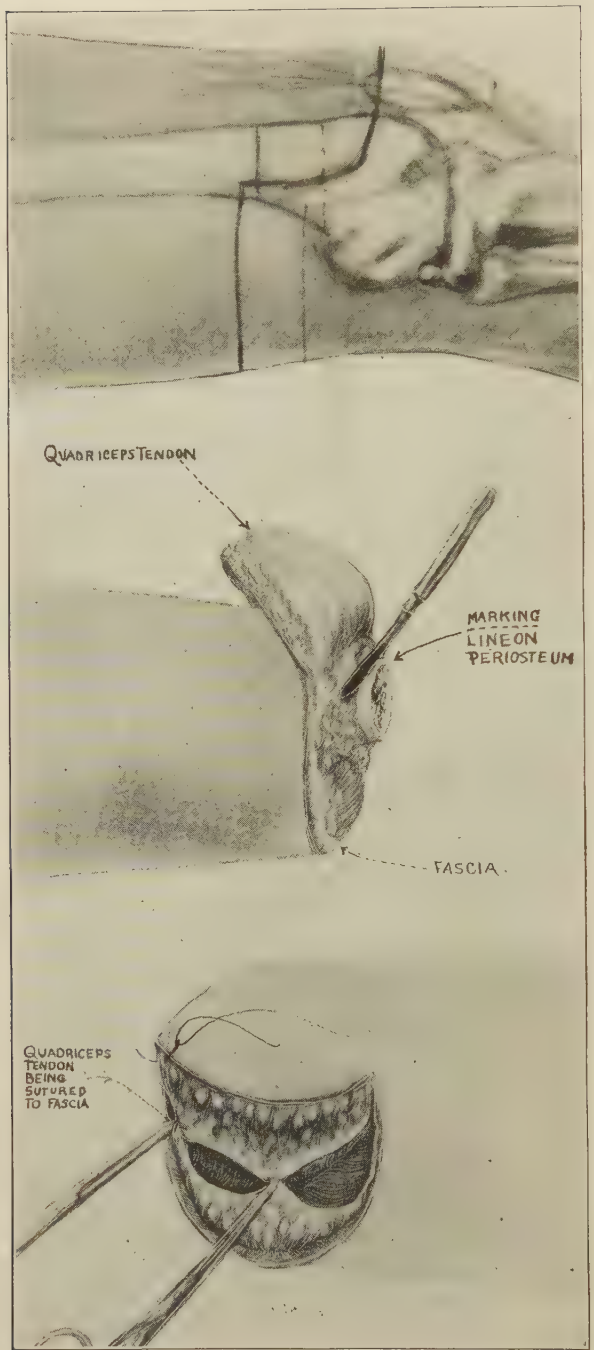


FIG. 19.—The end bearing thigh stump following the transcondylar aperiosteal tendoplastic method. Note symmetrically rounded stump, posterior suture line, absence of redundancy and irregularity. Patient is bearing full weight on stump end three weeks after amputation.



(A) Crudely shows the line of incision through the skin. The saw line of the bone is placed too far upon the shaft of the femur.

(B) The anterior flap consists of skin, fascia, quadriceps, tendon and the aponeurosis of the vasti laterally as they join the tendon. The fascia posteriorly is ¼ inch longer than the retracted skin. A quarter inch of periosteum is removed and the bone rounded off with a rasp.

(C) The quadriceps tendon and the aponeurosis of the vasti are secured to the fascia behind with towel clamps until sutured with plain gut. The skin is then closed, the scar falling posteriorly.

FIG. 20.—DIAGRAMMATIC REPRESENTATION IN OPERATIVE TECHNIQUE OF THE APERIOSTEAL, TRANSCONDYLAR, TENDO-PLASTIC AMPUTATION OF THE THIGH.

any synovial membrane adherent to the tendon is removed. Posteriorly the skin is dissected loose from the fascia to the depth of one-half an inch. The fascia is cut through parallel to, and a quarter of an inch below the skin margin. With an amputating knife, the remaining muscles, tendons, and soft parts are cut through to the bone.

The periosteum is cut circularly around the bone at the saw line with a knife, the soft parts are retracted, and the bone is sawed through at right angles to the thigh, not to the bone. One-quarter of an inch of periosteum is then removed and the bone rounded off with a rasp. The periosteum must not be shredded but cleanly removed and that left attached to the bone should not be loosened.

If the flaps have been properly cut, the anterior flap of tendon and muscle will fit snugly over the stump end, forming a suture line with the cut fascia and muscle posteriorly, U-shaped in outline, the top of the "U" correspondingly roughly to the base of the flap. The skin will likewise fall in place, making a perfect closure and allowing the skin suture line to fall just above the fascial tendon closure.

The tendon flap and posterior fascial layer are approximated by using towel clamps to relieve tension and secure them to their places until sutured. Interrupted No. 3 plain gut is used for suture. Prior to closure, the femoral vessels are picked up, dissected free, and doubly ligated with plain gut. The sciatic nerve, which is usually already divided, is pulled down, injected with absolute alcohol, ligated with No. 1 plain gut, to control bleeding from its accompanying vessel, cut with a sharp knife, and allowed to retract.

The tourniquet is removed, all bleeders are picked up and ligated, and the wound is closed as cited above. A through-and-through drain of rubber tissues for forty-eight hours is placed behind the musculotendon flap, coming out through the suture line. The skin is closed with interrupted silkworm gut.

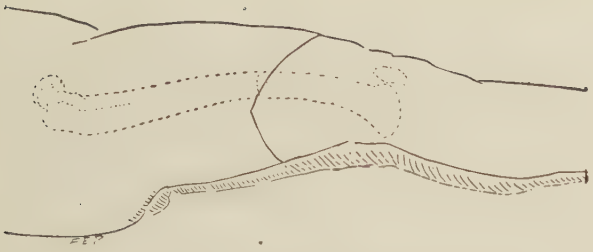
The stump is dressed at the end of forty-eight hours and daily

thereafter. If the anterior flap becomes reddish about the third or fourth day, and the patient complains of pain, skin traction should be applied as in the guillotine to overcome the powerful pull exerted by the quadriceps muscle against the tendon over the bone end. At the end of ten days, the patient is instructed to begin pounding the end of the stump with his hand, gently at first, but increasing daily in force and amount. The quadriceps muscle is fixed and cannot retract and the hamstring tendons are caught in the sutures posteriorly anchoring them.

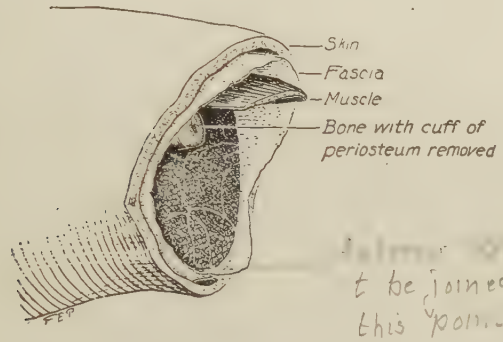
This method can be used following a disarticulation providing the quadriceps tendon has been preserved, in an ankylosed knee with the patella fixed, and does not require skin lower than the middle of the patella.

The amputation has proved so satisfactory, that it is considered the method of choice where a satisfactory stump cannot be obtained below the knee.

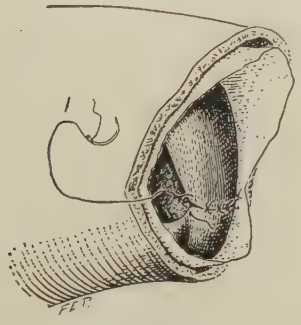
The lower third.—All stumps of this length should be end-bearing. This should be sought even if sacrifice of bone is necessary. The scar is preferably posterior to the bone end, obtained by using a longer anterior than a posterior flap. The fascia is sutured and the bone end covered with a thin pad of muscle to anchor opposing muscle groups and act as a buffer. The muscle pad soon becomes fibrous tissue and acts almost as well as does the quadriceps tendon for weight bearing, having the same thickness after it becomes fibrous tissue. In sectioning muscle, it will be found that the adductors and flexors contract more than the extensors. A muscle flap cut to suit the individual case from one group, as the extensor, brought over the bone end and sutured to the other groups in turn answers very well. The opposing muscles thus become anchored by a thin fibrous band, do not retract and continue to function. The bone should be rounded off and treated aperiosteally (Figure 21).



Showing line of incision for amputation in middle third of thigh



Showing skin, fascia, and muscle flaps cut, periosteum cut back from end of bone, and edges of bone rounded off.



Showing muscle flap being sewed down with skin and fascia flaps still free.

(A) Outline of skin flap and saw line. The anterior flap is longer than the posterior so that the suture line will fall posterior.

(B) Skin, fascia, muscle closure is essential. Note thinness of muscle flap cut from quadriceps group. The other muscle groups were so cut that they retracted circularly to the saw line. The skin and fascia are cut sufficiently long to afford closure.

(C) The flap of muscle from the quadriceps group not thicker than a quarter of an inch has been brought over the bone end and is being sutured by interrupted plain gut, to the other muscle group anchoring them so that they will not retract.

FIG. 21.—DIAGRAM ILLUSTRATING SURGICAL TECHNIQUE OF THE TREATMENT OF SOFT PARTS IN AN AMPUTATION THROUGH THE THIGH

The middle third.—Bone length should not be sacrificed above the lower third to improve a stump that is functionally useful. The so-called conical stump, where muscular atrophy and contraction has occurred leaving the bone prominent but well covered with skin, is a good stump. It acts as a lever equally as well as any other stump and to shorten it simply to improve its looks or to make it end-bearing in this location is never indicated. In a primary amputation, the same principle holds as in the lower third except that bone length is paramount over position of scar, end-bearing, or type of flaps used.

The upper third.—Here one-half an inch of bone length may decide whether a patient may be fitted with a tilting table as in a disarticulated hip, or whether he will be able to use a thigh bucket which is far more desirable.

No bone should be sacrificed and if it be a healed guillotine with an adherent scar or an unhealed one with a healthy bone, it should be closed by a plastic flap method without shortening. All stumps of four inches or less in length (bone length from perineum) will require a pelvic band when fitted to keep the appliance from pulling off the stump when the amputé sits down and to prevent the leg from turning on the stump when walking.

A stump shorter than three inches usually cannot be fitted with a thigh bucket. A bucket made to fit the individual stump built up snugly and high will be satisfactory where a proper fitting with a stock temporary prosthesis would be impossible.

Amputations through the neck or greater trochanter can be fitted equally as well with a "tilting table" as a disarticulation. They possess the advantages of causing the patient far less shock, are less extensive, more easily done, and the chances of success are greater. In clean cases the acetabulum must be filled with soft parts or dead

Fig. 22.—An excellent hip stump following the anterior racket method of using the long postero-internal flap of skin. Note a well rounded out buttock, absence of redundancy and a suture line well away from the rectum to prevent soiling.

space will result. If infection occurs, it is drained with difficulty and the retained cartilage suppurates.

The weight is borne on the tuberosity of the ischium in the tilting table. This is at a lower angle than the bone length in an amputation through the trochanters. When the bone length is longer yet too short for a thigh bucket, the stump may be carried in flexion, and if not covered with a large pad of soft parts, fits well in the tilting table bucket and need not be reamputated.

In a stump less than three inches in length, when reoperation is necessary, reamputation just below the greater trochanter or through the neck of the femur is advisable.

The Hip.—The hip stump should present a buttock equal in size and contour to its fellow, with the skin rounded out and smooth without sulci or redundancy. The tuberosity of the ischium covered with its normal covering of soft parts forms its base and there should be no excess of muscle or other soft parts near the groin to become pinched by the prosthesis. The scar is as far as possible from the rectum to prevent soiling (Figure 22).

Numerous operative methods are advised for cutting of skin flaps, control of hemorrhage, and treatment of periosteum. The following method is described in detail as it has given the ideal stump and has been found to be the simplest and most expeditious.

Anterior racket method.—The skin incision begins in the queue at the center of Poupart's ligament, extending downward over the femoral vessels for about three inches, then curves inward across the thigh to a point some three and a half inches below the groin on the inner side of the thigh, swinging back and upward across the posterior aspect of the thigh over the great trochanter, and thence to join the queue. The incision passes through the skin only. Through the original incision the femoral vessels are isolated, doubly ligated and sectioned, thereby controlling the main blood supply practically at

the first stage of the operation, making any type of tourniquet or compressor unnecessary. Other vessels are ligated as sectioned. Care must be taken that it is the common and not the superficial femoral that is ligated. The skin is now dissected free from the fascia, freely around its incised edge so that all muscles may be cut as close to their point of origin as possible.

Abduct the thigh, cutting the adductors through their tendinous origin; adduct, internally rotate, and cut the flexors and abductors as high as possible. Cut the muscles attached to the greater and lesser trochanter, taking care to leave no periosteum in the remaining soft parts.

Abduct and rotate the thigh outward, cut the capsule transversely, disarticulate or saw through the neck of the femur, leaving the head in acetabulum. Cut the remaining attached muscles from the femur and sciatic nerve, leaving only enough muscle substance in the stump to fill in the acetabulum if a disarticulation has been done, or to suture over the sawed neck of the femur. All muscle is removed then except that which forms the buttock.

After high transfixation of the great sciatic with a catgut ligature and its injection with alcohol, cut and allow it to retract. Treat the lesser sciatic and anterior crural nerves likewise. After all bleeding has been arrested, bring up the long interoposterior skin flap, reshape it so that it will fit snugly under slight tension and suture with silkworm gut. The suture line will fall to the upper outer side of the stump away from the rectum. This operation may be modified as already intimated in regard to the treatment of bone, i. e. a disarticulation, an amputation through the neck or through the trochanter may be done. All three give equally good stumps for fitting, the latter being slightly broader.

Providing the condition of the tissues allows, there is less shock

in amputation through the trochanter. The skin incision, if this type is selected, is modified.

Amputation through the neck appears the best as the head of the femur fills the acetabulum leaving no dead space that may follow a disarticulation and its incident sloughing of cartilage, ligaments, etc. It also probably occasions less shock.

The guillotine disarticulation is likewise performed through this incision, leaving more skin to allow for shrinkage and some of the adductor muscle and facia for its protection. All periosteum and other muscle should be removed and the wound left open. Later as infection is controlled and the wound heals, this interoposterior flap is easily pulled into place by the use of adhesive.

Chapter IV

THE GUILLOTINE STUMP

As was shown on Chapter I, the stump following the guillotine depends largely on the after-treatment. If skin traction is applied early and continued, and infection easily controlled or mild in degree, the wound heals in six weeks or two months giving a postero-terminal scar. Some few cases in the thigh can be fitted without further operation.

The improperly treated stump or one in which infection was severe, presents many different pathological conditions. At least ninety-five per cent of the guillotines of the lower extremity returning from overseas required some operative procedure before they could be classified as satisfactory stumps and fitted with temporary appliances (Figure 23).

The percentage in the arm and forearm was not as high as in these cases, as an adherent healed terminal scar gives a satisfactory stump.

The majority were unhealed, presented areas varying in size from that of a dime to the circumference of the stump, usually badly infected and accompanied by marked superficial and deep edema of the soft parts above. This edema was inflammatory. The tissues pitted on pressure and felt dense, thick, and resistant. The skin could not be lifted from the underlying tissues, and if incised oozed a watery serum. Dense scar tissue, underlying the healed area following prolonged suppuration, reduced the circulation, making healing impossible.

The dependent stump of the ambulatory amputé increased the congestion and also the edema, retarding the healing process.

Other cases presented protuding bone, usually covered with unhealthy infected granulations, with a healed circular, contracted scar above, corresponding to the line of retracted skin which cut off the circulation below making healing impossible.

The presence of lateral scars, three or more in number, extending upward from the stump end, following incisions above the amputation site to control infections in the soft parts, was not infrequent.

Redundant skin was occasionally seen but more often the skin was thrown into folds forming sulci due to the contraction of the underlying scar tissue. These sulci became irritated by the discharge from the unhealed area, presenting obstinate eczematous conditions. Persisting sinuses or large dirty granulations often indicated sequestration and osteomyelitis at the bone end. Below-knee stumps showed less retraction of soft parts than those in the thigh and less bone necrosis and sequestration. The fibula was almost invariably longer than the tibia and the crest of the latter usually had not been bevelled. Both conditions in the majority of cases required operation.

Types of Infecting Organisms.—The hemolytic streptococcus was present in a large percentage of the unhealed wounds. It persisted for a long period regardless of the type of germicidal agent used in dressing. The various strains of staphlococci, B. proteus, fusiform, and diphtheroid bacilli were reported. The colon bacillus was not isolated and reported as such. Typical infections with a virulent Klebs Loeffler bacillus occurred with the formation of false-membrane and accompanying toxic symptoms of the disease, in two cases causing death.

In routine examination numerous cases were reported as infected with the Klebs Loeffler bacillus which presented no local manifestation or systemic symptoms. They were probably the pseudo type or an avirulent strain.

Pre-Operative Treatment of the Unhealed Guillotine.—Routine *x*-ray; rest and elevation; skin traction; control of infection.

X-ray.—All stumps were *x*-rayed on admission to determine the condition of bone or presence of foreign bodies. Healed or apparently healed stumps may show definite sequestra in the bone end, excessive bony proliferation, or spur formation. Any attempt at treatment to render an unhealed area sterile in the presence of sequestration or extensive osteomyelitis of the bone end, prior to the removal of such pathological tissue, is time lost and increases hospitalization of the patient.

Rest and elevation.—The amputé has already spent a long time in bed. He gets around well on crutches, has no pain, and can see no reason why he should again go to bed and remain there. His wound can be dressed after a fashion and ambulatory skin traction applied by means of a Thomas splint without his being confined to bed, but the time required to obtain a wound ready for closure will be tripled.

Rest and elevation aid the healing process more than any other factor. The superficial and deep edema which has persisted for months gradually disappears; the circulation in the stump end improves and the congestion is lessened. This can seldom be accomplished by other means.

Skin traction.—Method of application is the same as used following the primary operation. Before the scar has contracted down and become fixed, two factors work against each other. The scar tissues as it heals contracts, while the elastic skin above constantly opposes its pull. The traction, by overcoming the pull of the elastic skin, aids the wound in its healing. In addition it increases skin length, pulling it down from above and stretching it to the limit of its elasticity. With the skin gained in this manner, a plastic closure will often be possible without the sacrifice of bone where it would have otherwise been impossible.

Control of infection.—The stump from the joint above its end should be cleanly shaven at all times and the skin around the wound under the dressings surgically clean. Dressings should be done by a medical officer when possible and not left to the nurse or ward attendant if good results are to be expected. Instrumental technic is used.

The germicidal agents giving the best results and ultimately adopted as routine were Dakin's solution and dichloramine-T. Gentian violet 1-1000 aqueous solution was used where the former could not be tolerated or on small areas with mild infection where strapping of adhesive was being used. It is not considered as satisfactory in virulent infections as the chlorine agents.

Dakin solution is applied with more or less difficulty to a flat surface but it was used in the presence of sloughing tissue following sequestrectomy and in deep wounds. It was the only agent that would control the more persistent hemolytic streptococcus infection. Dichloramine-T is more easily applied, requiring renewal only once in twenty-four hours, and was used as a routine in superficial non-sloughing areas.

The Carrel technic should be followed. The skin must be well protected with vaseline gauze when Dakin's solution is being used and with vaseline gauze or zinc-oxide ointment when dressed with dichloramine-T. All scabs and crusts are removed daily from the margins of the wound when dressed, the grease removed with benzine, ether, or alcohol, and the skin cleansed with neutral soap and water, followed by alcohol to remove all soap. The soap may be omitted and alcohol only used.

Cultures.—Secretions from the wound are cultured weekly to determine the type of the infecting organism and every other day a count made showing the number of organisms to the field, or of the

colonies grown on plated blood agar if hemolytic streptococcus is still present.

Diphtheria infection.—The case should at once be isolated when found infected with Klebs Loeffler bacillus and treated with diphtheria antitoxin subcutaneously and intravenously. The general treatment and care are the same as in any severe diphtheria. Dakinization of the wound is continued.

No operative procedure was attempted on the stump until the wound had been healed for sometime as the organisms have been demonstrated in the scar tissue long after the disappearance of the infection and healing of the wound.

Bone pathology.—Bone responds in two ways to infection depending upon its severity—by necrosis with sequestration and by proliferation. Both conditions are found together. Fortunately the osteomyelitis seen in amputation stumps is usually limited to the lower inch or two inches of bone. Drainage is usually adequate unless the bone end has been covered with muscle flaps which limit drainage and aid the infectious process.

Sequestra.—"Ring shaped" sequestra are frequently encountered, the lower quarter or half inch of the cortex becomes necrosed and separates circularly from the shaft. It shows definitely the saw line below with irregular serrated edges above where it has separated from the healthy shaft. Only a portion of the whole circumference of the shaft may be involved, a segment of the ring being necrosed or a scale of bone on its outer surface. All layers of the bone may necrose and sequestrate. The medullary canal is usually obliterated by formation of new bone and becomes sealed off from the infection below (Figure 3).

Terminal sequestra are frequently seen almost completely encased in proliferated new bone, growing out from the bone end, finger like, forming an involucrum and giving a cauliflower appearance. Large

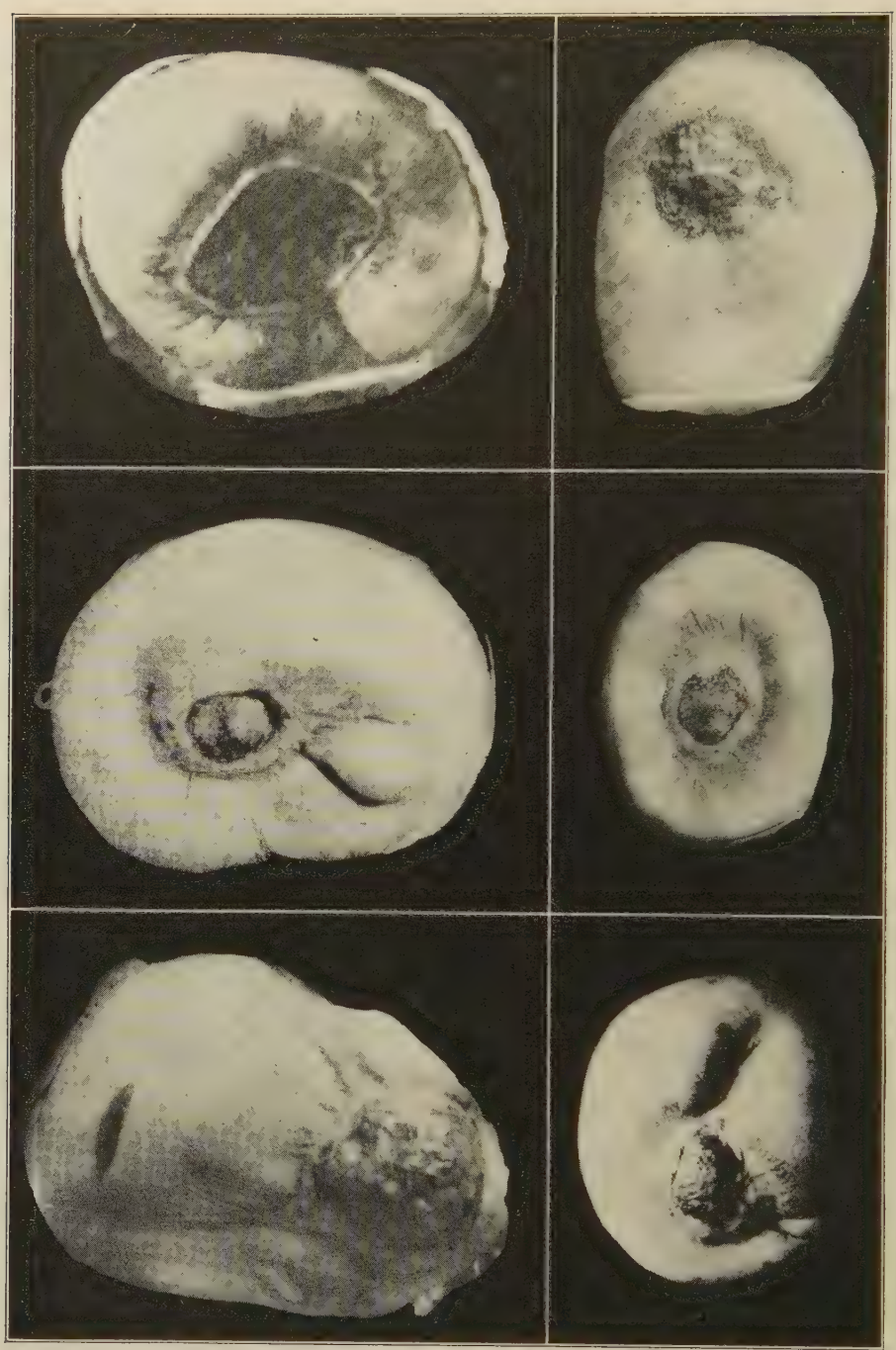


FIG. 23.—Partially healed guillotine stumps before plastic closure. Note unhealed areas, scar tissue, sulci, redundant skin, etc., following war wounds. They clearly demonstrate why some of them will never heal and none would make satisfactory stumps without surgical repair.

Fig. 24.—Osteomyelitis and sequestrum in a femur stump showing involucrum. After removal of the sequestrum, proper drainage and dakinization, the femur reformed and reamputation was not required.

sequestra, three or four inches in length, representing the outer third of the shaft of the femur have been removed. In one case shown in the accompanying radiogram, the lower four and a half inches of the femur sequestrated and was wholly encased in a thick involucrum (Figure 24).

Spurs.—Large bony spurs extending into the adductors in the thigh, terminal in the tibia and fibula were seen. The longer spurs in the thigh and all terminal spurs in the leg required removal.

Periosteum.—Periostitis frequently occurred extending upward two or three inches along the shaft of the bone. The thickening gradually subsided as the infectious process lessened. Definite large proliferated thickened masses of semi-bone consistency occurred extending upward on the shaft an inch to an inch and a half above the saw line. Trauma and stripping of the periosteum at the time of amputation no doubt played a part in this. Large masses of new bone formation which had become definitely calcified resembling in form twigs of a bush were found in the soft parts and required removal. This was encountered in the thigh where apparently the periosteum had been stripped at amputation from the bone below the saw line and allowed to remain, and in practically all disarticulated hips, the disarticulation having been done subperiosteally above the great trochanter, according to the erroneous teaching of the past. Infection undoubtedly stimulated the osteogenetic layer of the periosteum to greater proliferation.

It is believed that the spurs cited have their origin in improperly or carelessly treated periosteum plus the stimulus of the infectious process. The periosteum was loosened from the bone when the soft parts were retracted or pulled loose by the strong adductor muscles and the spur growth began. Again those seen posteriorly have as their base the linea aspera where the bone is last sawed through and

where the periosteum will be torn if care is not taken. They are far less frequent on the anterior and external surface of the bone.

When should plastic closure be attempted?—Theoretically no surgery should be done in the way of a plastic closure or repair of an unsatisfactory stump, except for removal of sequestra, until six months after healing, due to the possible presence of latent infection in the scar tissue. The rule is carried out by the neuro-surgeon, the bone surgeon, and usually in plastic work elsewhere on scar tissue. If this rule were adhered to in the stump, many would not be closed for years. It is impracticable in the large number of amputés and it is not necessary. Certain rules must be followed, however, or the results will be failures.

Edema.—The stump must be free from superficial and deep edema. Its disappearance is marked by a rapid, often sudden shrinking of the stump. The skin again feels thin and loose and can be raised in folds and no longer pits on pressure. The whole stump becomes flabby and pliable.

Types of infection.—No operative procedure is safe in the presence of the hemolytic streptococcus. The bacterial count should not show more than one organism to the field. The unhealed area should present healthy granulations and look clean. This often gives a better index in the absence of hemolytic streptococcus than the bacterial count. The two are given equal weight in determining when to operate. In two leg stump cases the hemolytic streptococcus infection persisted regardless of time and treatment. The granulation tissue and skin margins were burned away with actual cautery followed by Dakinization without result. They were finally closed regardless of this organism's presence. Both became infected but finally healed without further operative treatment, and presented very satisfactory stumps eventually.

Sinuses.—The wound should be free from sinuses. The cause of

the sinus and the sinus itself should first be removed and the wound sterilized.

Bone.—The *x*-ray should show no evidence of osteomyelitis or sequestration. A mild periostitis does not contraindicate closure. Bony spurs and proliferation showing no evidence of infection may be removed at the time of closure.

Eczema.—Eczematous conditions in sulci and around redundant skin must be under control, as their secretions are infectious.

Skin traction.—The maximum should be obtained from skin traction prior to operation when it is indicated and the skin itself should be clean and healthy.

General condition of the patient.—This should be good and usually improves during the preliminary treatment of the unhealed stump. The operation is delayed until the maximum of the patient's resistance to the particular infecting organism is reached. We must remember that we are always working in a contaminated if not an infected area.

Latent infection.—The presence or absence of edema and the condition of the unhealed area give a fair index to the latent infection present. As severe infections have been encountered following plastic operations on healed as well as on unhealed stumps, latent infection is present in scar tissue under the skin, around the bone end, and in the lymph spaces. The size of the unhealed area, providing it is sterile, does not increase the operative risk.

Operative treatment.—In a primary one stage operation musculofascial closure is essential. This is not true in the repair of secondary plastic surgery of the guillotine stump. The muscle and fascia have become fixed to the bone by virtue of the scar and fibrous tissue formed during the healing process. Muscular retraction with excessive conical stump formation and protruding of the bone end will not occur under these circumstances. The fibrous tissue not only

FIG. 25—A short, 4-inch thigh stump following the repair of a guillotine giving excellent function when fitted with ischial bucket with pelvic band.

affords fixation but also acts as a substitute for the fascia as a non-elastic covering, restoring normal physiological conditions and requirements.

It is not necessary in this work to shorten the bone so that its end will be covered by muscle or that a complete fascial closure be effected. A highly satisfactory stump is obtained by skin closure only (Figure 25).

The guillotine was done to give the maximum bone length. It should not be shortened at this date after weeks or months of treatment to obtain it, due to a faulty former belief as to the essentials for making a satisfactory stump.

Secondary closure.—At the end of a week or ten days following the guillotine the wound may become sterile and a secondary suture may be possible as outlined in Carrel's work. Such a procedure in a flapless guillotine is extremely wasteful to say the least. The inelastic fascia cut equal in length with the bone cannot be sutured without considerable bone shortening, three inches or more in a fleshy thigh, and its suture at this time is essential. Unless the flap guillotine was originally done, secondary closure is not advisable. This bone length can be saved by continuing the skin traction for a few weeks longer.

Pre-operative preparation.—When it has been decided that the stump can be safely operated upon, and in deciding this the size of the unhealed area, providing the maximum skin length has been obtained by traction, is not considered, the following routine preparation is followed: On the day preceding, the stump from the lower end to the joint above should be washed with soap and water, shaved, dried with alcohol, and then thoroughly cleansed with benzine to remove all fats and oils resulting from protectives used on the skin in the form of ointments or vaseline. The stump is then dressed with dry sterile gauze with an alcohol compress against the unhealed area. On the morning of the operation the stump is again cleansed

with benzine, allowed to dry thoroughly, painted with fresh three and a half per cent tincture of iodine and a sterile dressing applied an hour or more before operation. After the patient has been anesthetized, the dressing is removed and the stump repainted with three and a half per cent tincture of iodine. Any unhealed areas should be painted last.

Operative methods.—Operative procedures not considering sequestrectomy and methods used to control infection or to remove foreign bodies are classified as: 1. Plastic Closure; 2. Plastic Resection; 3. Re-amputation.

Plastic closure.—This method is applicable where sufficient soft parts are available to give good skin closure, removing no more than one-eighth of an inch of bone that may be adherent to scar where its end is irregular in contour or where there is a terminal spur.

The skin is incised through healthy skin only, as close to the scar as possible. It is best to make this incision so that all healthy skin will remain and all scar and unhealed tissue will be removed. If flaps are shaped at this period, it may later be found that skin removed could have been used to advantage.

All scar tissue is removed, cutting close to but not into the muscle. The incision should not be made through muscle planes unless this is necessary on account of muscular redundancy. The scar tissue contains latent infection but its resistance and that of the walled off muscles is far greater than newly incised muscle planes. If adherent to the bone, a thin sliver of bone is removed with it. The scar tissue, unhealed area and adherent fragment of bone having been removed en masse, one-fourth of an inch cuff of periosteum is removed with bone forceps. The skin is now dissected loose from the underlying scar tissue and fascia, lifting all the subcutaneous tissue with it. If this dissection is carried upward for one to three inches, it becomes well freed and its elasticity can be used to advantage. The

skin is freed by cutting with a sharp knife and not by a scraping method as used in dissection. Clamps should never be applied to the skin and all tissues handled gently to reduce trauma to a minimum. Having excised the scar and treated the bone, a survey is made of available skin. The suture line preferably should not be over the bone end. The toughest and best skin should be used when there is any choice. The meeting of three or more suture lines at one point is to be avoided. After determining where the skin can best be approximated without much tension, the flaps are shaped so that there will remain no redundancy sulci or "ears." Any neuroma so encountered are dissected out and the nerve properly shortened. The skin does not become fixed to the bone end unless severe infection follows.

The tourniquet is not required in the plastic repair of guillotine stumps and any bleeders that are encountered are clamped as cut. The results without its use are believed to be better. The bleeding from the scar tissue is troublesome and difficult to control. Hot normal salt compresses aid. Complete hemostasis is essential.

After controlling hemorrhage, the skin is closed by interrupted silk worm gut. Traction stitches to relieve tension are of value, suture over buttons or rubber tubing is not as good as skin necrosis from pressure is almost invariable. If it is necessary to close the flaps under tension, scarification of the skin will relieve congestion. Forty-eight hours drainage is established using rubber tissue. If the suture line at the time of the first dressing appears to be under tension, skin traction should be applied at once.

Plastic resection.—Where the bone is protruding and covered only with granulations or where there is marked proliferation at its end following improper treatment of the periosteum and infection, some of its length will have to be sacrificed. Where the bone condition is good and spurs only are present, they may be removed without shortening of the bone itself. The skin is incised as in the plastic

closure, the scar tissue cut free as close to the healthy muscle as possible. The skin and muscle are retracted and freed from the bone back of the scar to the saw line. The bone is sawed through after incising the periosteum circularly.

The scar, unhealed area and the bone are then removed en masse. One-quarter of an inch cuff of periosteum is removed and the bone rounded off with bone forceps. The musculo fibrous layer which has been freed is sutured over the bone end. The skin is closed and drainage established as cited above.

Reamputation.—Reamputation should be done only when the stump length is either so long that it is unsatisfactory or so short that the stump cannot be fitted. It may be necessary due to a bony or fibrous ankylosis of the joint above. The incision is made through healthy soft parts above the infected area and a closure of fascia and muscle is done as in the one stage primary amputation. Removal of more bone is necessary than in either of the two former operative procedures. Reamputation should not be done except for the reasons stated. Fresh muscle planes are cut through and nerves again must be shortened.

The method was resorted to in two syphilitics after a course of intensive anti-syphilitic treatment where the terminal unhealed granuloma refused to improve. Two inches of bone were sacrificed, but in both cases healing was by primary union. Each had been treated for six months without results in an attempt to heal the original wound.

Skin graft.—Skin grafts are unsatisfactory in stumps of the leg and thigh. Healthy skin with intact nerve supply is necessary to stand the constant pressure and strain brought to bear on it. The skin graft is not thick enough, its elasticity is less and it is almost constantly irritated. It may be used to a limited extent in the arm and forearm where less pressure occurs. Unhealed areas can almost

invariably be closed with the use of skin traction and some plastic procedure of the skin on the stump.

Pedunculated flaps from the other leg.—The unhealed area can be closed in this manner and the pedicle cut after circulation has been established. The flap, however, lacks nerve supply and therefore is subject to trophic changes. Any constant weight or strain occasioned by the artificial appliance causes ulceration and necrosis. The results following skin grafting are better. It is not believed that a satisfactory stump can be obtained by this method.

Sliding flap from the stump.—After incising all scar tissue it will frequently be found impossible to close the skin by either an antero posterior or lateral suture without bone shortening. The skin should be dissected loose from the fascia to the depth of two inches or more so that the maximum of mobility and elasticity is gained.

Cutting of flap.—A flap of skin is cut so that the blood supply to its base will be the maximum large enough to cover the stump end and when possible so that the bone end will be covered by the body of the flap. An incision is made beginning at the skin margin extending upward on the stump, at right angles, to a depth corresponding to the breadth of the flap desired. The incision is then carried parallel to the stump end and at practically a right angle to the first incision, its length being determined by the length of the flap desired (Figure 16).

The base of the flap must be as broad as any other part of the flap. The length may be greater. The flap is carried across the stump end and secured in placed by towel clamps until sutured. The area from which it is removed is covered by pulling up the corner formed at the point where the incision was first made. Approximation must be exact so that early healing and the new circulation may be established. Healthy skin only, free from scar tissue, should be used and the flap and its base should be thoroughly scarified.

FIG. 16.—ILLUSTRATION DEMONSTRATING SLIDING FLAP METHOD

(A) Skin incision with edges marked with differentiating lines showing how approximated for suture.

(B) Skin flap secured in position by towel clips ready for suture. Skin has not yet been scarified.

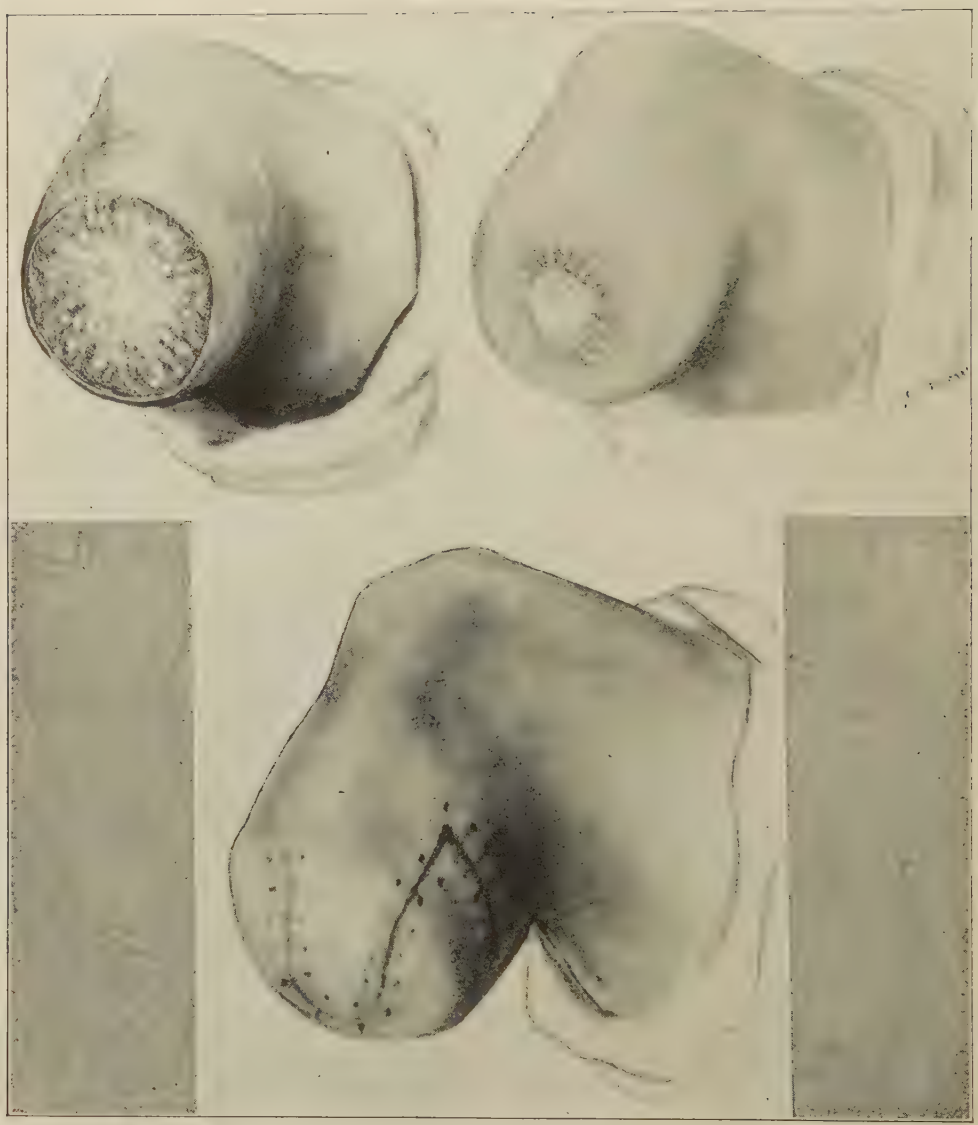


FIG. 17.

(A) Short below knee stump, unhealed area the diameter of the stump end.
(B) After three weeks skin traction.
(C) Stump after plastic sliding flap closure without bone shortening.

Necrosis occurs from venous congestion and is not due to the cutting off of arterial supply. Thorough scarification of the entire flap, particularly its base, is essential. The scarification relieves the congestion and is essential to the life of the flap. The healing of the stump after such a method of closure takes a longer time but bone length is saved and the end result is highly satisfactory (Figures 17 and 18). In the short below-knee stump the removal of the fibular head gives additional skin.

Sequestrectomy.—Two different types of sequestrectomy are seen if classified from an operative standpoint.

In one the sequestrum is free to a greater or less extent covered only with soft parts, with an unhealed, infected stump or a freely discharging sinus. In the other, the sequestrum is usually small and surrounded with new bone formation, the unhealed stump is comparatively clean or a small sinus exists.

In either case any half way measure by attempting to remove the sequestrum through a small incision or by opening, scraping with a curette and doing a partial or complete closure is a waste of time and followed by more bone necrosis and an increase in scar tissue.

In the presence of definite infection with free sequestrum, the whole scar tissue en masse, all necrotic tissue, and the sequestrum is removed en toto. The skin incisions are made at the junction of the skin and scar tissue. The opening of fresh muscle planes is avoided. The bone end should be rounded off with bone forceps removing the irregular, newly formed bone and thickened periosteum. The medullary canal is usually found closed by the formation of a newly formed bone plug, one-half inch or more above its end. The wound should be left open, Dakinization started at once and skin traction applied. If all necrotic tissue is removed at the time of operation little sloughing will follow. The Dakin solution can soon be replaced by dichloramine T dressing. The wound soon becomes sterile, heals

Fig. 18.—Mid thigh stump following plastic closure of guillotine amputation using sliding flap method and thereby saving 2 inches or more stump length. The stump is distorted because of position in which photographed. The outlines of the flap and the healed points of scarification can be made out, however.

quickly from the bone outward with a minimum of scar tissue, retaining little or no infection and the bone by virtue of proper drainage becomes clean. This can soon be followed by a plastic closure. Skin traction as in the guillotine is begun at once.

In the second class where the wound is comparatively clean and practically healed and the sequestrum is covered with an involucrum giving the bone a cauliflower appearance, primary closure with primary union can usually be done. The case is treated as in a plastic resection. The scar tissue, sinus and bone end is removed en masse. The bone is sawed through above and as close to the newly formed bone and sequestrum as possible without opening into the infected masse and above the bone plug sealing the marrow cavity. If pus is encountered during the procedure, the wound is left open and Dakinized.

Spurs.—Bony spurs when not terminal or large enough to cause pain and when well covered with muscle tissue do not in themselves call for operation. They become rounded off and may to a certain extent become absorbed after the stump is fitted. They may, however, become more prominent and apparently increase in size. This is due to the atrophy and shrinkage of the muscle covering them. They should be removed as a matter of routine at the time the plastic repair of the stump is done. The terminal spur is removed by sawing off a thin sliver of the bone end and rounding it off after removing a periosteal cuff. With large spurs, particularly those seen in the adductors, the periosteum is incised around their base, they are cut free with a mallet and chisel and dissected loose from the muscular tissue. Two or three large blood vessels are usually cut while removing the spur from the deep muscles. They are controlled and tied with difficulty. All periosteum is removed from the soft parts to prevent recurrence and is cut free around the base. The base is rounded off with bone forceps. The muscle must be sutured after removal

of protruding spurs to obliterate dead space left. Quite frequently it will be necessary to remove one-half inch to one inch of bone to get rid of the excessive new bone formation and give a bone end, treated aperiosteally that will be painless.

Sinuses.—A sinus may lead to dead bone, a metallic foreign body, non-absorbed ligature or may result from dead space in scar tissue due to the fact that the walls of the sinus are not collapsible. In the first two, the X-ray should give a diagnosis. The tract should be injected with a aqueous methylene blue solution and excised or dissected out in toto. Curetting of such a sinus tract is of little value. If the excision can be made through healthy tissues, the wound should be closed, otherwise it should be left open and sterilized. Probes should not be introduced into sinuses, nothing is gained by their use and new tracts may be opened with a spread of infectious process.

Post-operative care.—A tight dressing is applied after closure of the wound and the stump protected with a gauze and cotton pad. A tight dressing diminishes dead space and lessens post operative edema and the occurrence of blood clot formation under the flaps. It is practically impossible to control all blood oozing, particularly from scar tissue.

Below the knee stumps should be splinted in extension for the first week. In the short stump a certain amount of flexion deformity will always occur which will require time and treatment to overcome. The splint limits movement while the patient is still asleep, prevents violent clonic spasms which frequently occur, thereby lessening causes which aid in exciting hemorrhage. The knee should be slightly flexed to lessen pain which even then is complained of. Splints are not required in the thigh, arm or forearm.

When the patient is returned to bed, the stump should be elevated on pillows and should be moved as little as possible during the first forty-eight hours. The after treatment of the stump requires

constant attention and daily dressings following the first forty-eight hours until the wound is healed, if satisfactory results are to be expected. Mild infection is not infrequent due to the latent infection present in the scar tissue, but is usually controlled easily if recognized early and proper treatment instituted at once. Time is lost when infection occurs but ninety-five per cent of the stumps give practically as good functional results as those healed by primary union.

Dressings.—Instrumental technique is recommended. The stump should be dressed at the end of forty-eight hours when the drainage is removed unless there is evidence of hemorrhage having occurred or of beginning infection. The stump is cleansed with alcohol and a dry dressing applied. If there is any oozing or redness, the first layer of gauze applied is saturated with alcohol. If at the first dressing or later, the skin gives evidence of being under too much tension and the stitches are cutting, skin traction is applied at once. This saved many stumps when the skin was closed under tension, where the bone end was covered only with skin and its elastic pull exerting pressure caused a beginning necrosis.

Alcohol compresses will control most superficial stitch infections. The stitches are not removed until the eighth or tenth day unless there is some particular indication and spreading of the suture line is lessened by direct strapping with adhesive plaster for the following week.

The stump at all times is tightly bandaged to lessen post-operative edema by maintaining a firm outside even pressure. This is particularly true following the first dressing. A patient with an amputation of the upper extremity may be up in a week but with one of the lower extremity, he should remain in bed until the stitches are removed and the wound healed.

Pain.—All cases require opiates to relieve pain the first and often the second night following amputation or plastic closure. Pain

is a symptom that varies with the individual. Severe and persistent pain following a few hours after closure may be due to hemorrhage, yet it may often be relieved by loosening a splint or bandage or changing the position of the stump.

Hemorrhage.—Hemorrhage under the flap usually occurs during the first forty-eight hours, causing severe pain and swelling of the stump and is indicated later by the bluish discoloration under the skin where the clot has formed. It is essential to secure all bleeders as a clot may spoil an otherwise excellent stump. The temperature and pulse reaction following the formation of extensive blood clot even in the absence of infection may be severe. The bleeding following plastics was usually due to oozing from scar tissue. To open such a stump with the idea of finding and ligating a bleeding point is useless. If it is believed that bleeding is due to a "spurter," the patient should be anesthetized, the stump opened and the bleeding point secured. More often the hemorrhage can be controlled by less drastic means. A tight bandage should be applied and the stump elevated. Horse serum in from twenty to thirty cc doses has given excellent results in controlling such oozing.

If a clot has formed in the stump it must be removed. One or more stitches on the side of the stump most dependent to the clot are taken out; the skin flap raised with blunt forceps and one or more Carrel tubes introduced. The opening should never be made over or near the bone end. The clot can gradually be dissolved and removed by Dakinization. The wound is treated practically the same as in infected one. The skin edges that were opened for the introduction of the Carrel tubes are pulled together with adhesive after the removal of the clot and the stump will usually heal, requiring no further operative treatment. It will seldom, if ever, be necessary to open up the entire wound to treat the condition or to remove the clot.

Infection.—Infection usually occurs from three to five days following operation. It may be mild or severe. The patient complains of throbbing pain in the stump and there is elevation of temperature and pulse. The stump looks red, the amount of edema is increased and there may or may not be a discharge of serum or pus from the suture line or drainage tract. This can usually be controlled in a few days by the application of hot boric acid dressings and the institution of dependent drainage or by the removal of lateral sutures, the introduction of Carrel tubes and Dakinization underneath the flaps. Sutures should never be cut at or near the bone end. If the suture line begins to separate, skin traction should be applied at once.

After the wound has been sterlized, the tubes are removed and the suture line or unhealed areas are drawn together and strapped with zinc oxide adhesive. The number of cases requiring re-operation that become infected is very small. Bone necrosis or sequestration is rare.

Erysipeloid infections.—A condition has been observed in stumps and in other war wounds which clinically has a marked resemblance to erysipelas. Its occurrence is sudden with a marked elevation of temperature from 103 to 104, prostration, headache and at times accompanied with nausea and vomiting. The skin over the stump becomes a beefy red, is thickened, hot to the touch, painful and spreads upward with a more or less well defined line of demarcation. Suppuration never occurs. The whole stump length is usually involved. The symptoms, local and general, gradually subside beginning on about the fifth day following the onset. It occasionally follows some operative interference but more often occurs during the pre-operative stage of the stump. Usually there can be found no direct exciting cause. It is probably due to some form of streptococcus which infects the skin lymphatics, having become changed in its virulence and ordinary properties of pus production due to its long habitation in the

infected scar tissue. These cases were isolated but cross infection was never seen.

Local heat, cold or ichthyol dressings may be employed. None seem to lessen or influence the course of the infection. Whatever type of dressing that is most comfortable to the patient should be used.

Tetanus.—Orders from the Surgeon General's Office directed that all patients with post-war wounds which were operated on be given 500 units of anti-tetanic serum. This has been given as a routine following operation, while the patient was still anesthetized in order to prevent anaphylatic shock. Some patients have developed local tenderness and swelling at the site of injection and have run a low grade temperature for a few days which was attributed to the anti-toxin. A local and sometimes a general urticaria has developed. This was easily controlled by the use of chlorotone in five grain doses or by adrenalin hypodermically.

Chapter V

THE CARE OF THE STUMP—JOINT DEFORMITIES

Early functional use of the stump is essential in order to (1) secure a painless stump free from bony exostosis, edema and tender points; (2) to strengthen and develop musculature necessary for its use and to mobilize its joints; (3) to make the amputé ambulatory without the use of crutches and to return him to civil life as early as possible, ready to take up his old occupation or to train him for a new life work.

The average case in which primary union has occurred can be fitted six weeks after operation. The earlier the case can be fitted with a temporary prosthesis, the better the end result. This six weeks could be divided into two periods of two and four weeks each. The first period may be prolonged due to infection, the cutting of skin stitches, hemorrhage, non-absorption of catgut ligature, or non-healing of the wound. The stump is snugly bandaged at all times and elevated on pillows or splinted to lessen edema, and during the first four days to lessen hemorrhage. After the fourth day unless there is some contra-indication, the patient is directed to move the stump in all directions, increasing the force and amount of movement daily. Special attention is paid to the skin and alcohol is freely used in dressing to dry up secretion and to toughen it.

In thigh stumps, particularly the short ones, where flexion deformity is most apt to develop, the pillows should be removed once or twice daily from under the stump and placed under the buttocks, thus allowing the stump to drop in hyperextension.

The second period begins on healing of the wound. The treat-

ment during this time has as its object the preparation of the stump for its fitting. The joints above the stump should have a free and full range of motion, the muscle should be developed to give the maximum leverage afforded by the bone length. The stump should be free from superficial and deep edema and the skin should be toughened and free from infection. To bring about this, the following daily routine is carried out:

1. *Massage.*—The stump should be massaged daily from ten to thirty minutes. When the massage is first started, the region of the incision is avoided and massage should be light enough not to cause undue tension on the fresh scar. As rapidly as the condition of the stump will permit, the depth and force of the massage is increased up to the limit. In the stump where healing has been delayed by infection, the reaction to early massage must be carefully watched or infection may again light up. Adherent scars are rendered much less so by the increased circulation to the part following persistent massage, and manual manipulation.

2. *Bandaging.*—After massage, the stump is tightly bandaged with an elastic bandage or a flannel bandage cut on the bias. It must be properly and carefully applied, giving a firm even pressure throughout, and is secured in place to keep it from slipping off. It is applied by the masseuse immediately after massage. The massage and bandage should continue even after the patient has been fitted. They increase the circulation to the stump, thereby removing the post-operative edema, improve nutrition of the muscle substance and lessen bone proliferation. The skin becomes tougher and the shrinkage of non-functioning soft parts is hastened. The bandage is always applied to the stump when the artificial appliance is not worn. Shrinkage in large, flabby, fat thigh stumps may be increased by applying the bandage wet before the patient goes to bed at night.

3. *Pressure exercises.*—Where end bearing is desired, the

patient is directed as early as the tenth day following operation to pound the end of his bandaged stump with the palm of his hand, gently at first, at four to six-hour intervals, not hard enough to cause any reaction or pain, and to gradually increase its force and frequency. Later he should stand on his stump end at first on a soft pillow and after it has become toughened on a flat wooden surface.

4. *Movements.*—At the time the stump is massaged, passive and active movements are made in all directions to the full limits of the joint motion. Classes in stump calisthenics should be organized, grouped as arms, forearms, thighs and legs and put through a series of setting up exercises for half an hour daily. The amputé generally gets entirely too little exercises and too much food. These exercises increase the general muscle tone of the patient as well as that of the stump. Some form of resistant movements should be included to still further strengthen the stump muscles and increase the vitality of the bone. Marked osteoporosis and absorption are seen at operation in the long bones from non-use in a stump which has not functioned for a long period. This form of exercise is mandatory where limitation of motion exists.

5. *Baths.*—Hydrotherapy in the form of hot packs, warm baths, either water or electric when indicated improve the circulation and hasten absorption. The contrast bath is particularly valuable in stumps showing poor vascular tone and where there is excessive subdurmal connective tissue with persistent edema. It, however, softens the skin and delays fitting. The skin must be toughened up after its use before the use of the prosthesis is allowed.

The routine described above should be followed in all cases. The massage increases the circulation, improving the tone of the skin and muscles, rapidly removes post-operative edema and loosens up adherent scars. Muscular power is necessary to manipulate the prosthesis and this can only be developed by muscular exercises. Pound-

ing and pressure over the stump end aids in lessening spur formation and tender points at the bone end. After the stump has been fitted, particular attention must be paid to the skin, especially in warm weather. The stump should be thoroughly washed nightly with soap and water, followed by a bath in cold water. This is followed with an alcohol rub or the use of a weak formaldehyde solution. Stump socks should be washed daily and care should be taken to remove all soap before drying. Talcum powder is used freely to lessen friction in the recently fitted stump and pressure points inspected and relieved by early adjustments of the prosthesis. The tight flannel bandage is applied as soon as prosthesis is removed and worn during the night until the circulation and soft parts have become adapted to the use of the prosthesis. Skin infections are not infrequent and require early treatment. Abrasion occurs at times and should be strapped with adhesive.

Dermatitis.—Persistent eczematous conditions are often seen. Some respond early to treatment and others are very persistent. The most frequent causes are sinuses, skin infections, irritations of drugs, sulci caused by redundant skin and scar tissue and by hyper-susceptibility of the skin.

In the treatment of the condition, the cause should be found and if possible removed. A great many of these conditions had their origin in the use of Dakin's solution or dichloramine T without proper skin protection. Five per cent. ammoniated mercury ointment gave excellent results in some cases; others responded to a weak salicylic ointment and Lassor's paste was found useful for skin protection in the discharging sulcus or sinus type. The x-ray gave excellent results in certain resistant chronic types.

Joint Deformities

Prevention.—The deformities of joints above amputation stumps are for the most part preventable. The amputé requires the complete use of the joints of his stump to enable him to use his prosthesis properly. The contractures which occur through neglect impair the use of the stump and in some cases render it useless until corrected or a re-amputation is performed above. Daily exercises of the joint through its full range of motion should be started as early after operation as the condition of the stump will allow.

Early and continuous skin traction in the guillotine stump in addition to preventing retraction of soft parts reduced joint contractures and deformities to a minimum. The common contractures seen were as follows, occurring most frequently in the order named:

Shoulder.—Adduction deformity was present particularly in all arm stumps regardless of length.

Knee.—Flexion deformity particularly in the short stumps. The stump is always carried partially flexed when walking and its most restful position while in bed is in flexion.

Foot.—All stumps show an equinus deformity when the pull of the tendo Achilles is unopposed or weakly opposed.

Hip.—Flexion occurs particularly in amputations above the middle third and is associated with abduction.

Elbow.—Flexion deformity occasionally occurs if the stump is carried too long in a sling.

Treatment.—A routine examination should be made for joint contractures and proper treatment at once instituted. These deformities may be due to muscular contractures, fibrous changes in the joints and their ligaments, or to bony ankylosis. The majority of contractures excluding those due to bony changes can be overcome

to a greater or less degree by massage, manipulation and resistant exercises.

Forced manipulation under an anesthetic should rarely be attempted.

When a large number of cases are being treated all those showing limitation of motion should be formed into classes for instruction in definite curative exercises daily, in addition to the massage and manual manipulation.

Foot.—Contractures about the foot due to unopposed pull of the tendo Achilles require tenotomy. They usually recur and a reamputation is advisable unless the insertion of the tibialis anticus, posticus and peroncii muscles is intact.

Knee.—Flexion particularly in the short stump will frequently not respond to massage, manipulation or traction. The wedged plaster cast method was found most satisfactory in treating this deformity. The cast is applied over the stump and knee, extending well up on the thigh, the leg being extended to its limit. At weekly intervals a "V" shaped section of the cast is removed anteriorly and the cast cut through posteriorly. The leg is extended to its limit and plaster applied to hold it in position. Very persistent and long standing cases respond to this method (Figure 26).

Various mechanical splints worked by levers and screws to exert a constant pull to overcome knee flexion were found unsatisfactory. The stump was often so short that a proper fixation could not be obtained. It was cumbersome and annoying to the patient and was worn by him only when watched.

Bony ankylosis of a knee in which there is more than ten per cent limitation in extension or marked loss of flexion requires reamputation through the condyles of the femur.

Hip.—Flexion and abductor deformities of short thigh stumps are often most persistent. An open operation incising the joint cap-

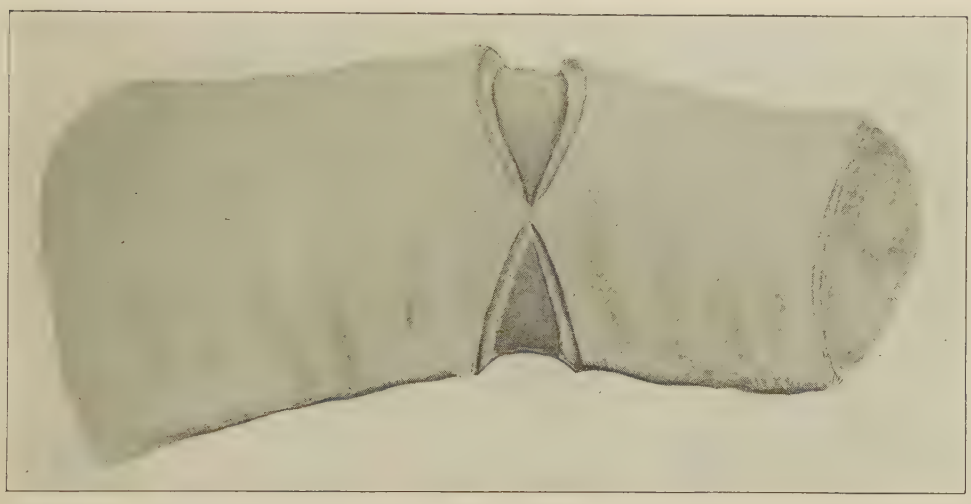


FIG. 26.—The wedged plaster method for correction of flexion deformities in the knee. A plaster cast is applied extending from the stump end well up the thigh with the leg extended. At the end of each week a wedge is cut anteriorly and a slit behind, the leg is extended to its maximum and plaster applied to hold position.

sule anteriorly and the Psoas and Iliacus muscles may become necessary, or the patient, unless the deformity is marked, after proper fitting, may be able to function, using the compensation afforded him by the pelvis or spine.

A strong masseur should carry on the daily massage and manipulations. The patient is placed face downward on the massage table. The masseur lifts the stump upward with one hand while he exerts pressure downward on the pelvis with the other.

A special massage table so constructed as to allow a broad webbing band to extend over the stump and down through its middle to the floor is of value. Sandbags may be placed in the lower loop of the webbing to cause constant pull downward, while the soft parts in the region of the joint are being massaged. The patient is tilted toward his sound side so that the traction on his stump corrects the abduction at the same time. The opposite thigh is held in flexion by means of a webbing strap secured to the upper end of the table fixing the pelvis.

Body ankylosis in a short thigh stump or where there is marked deformity requires amputation through the neck or trochanter of the femur or disarticulation.

When there is a good length thigh stump and the ankylosis has occurred in good position, the patient can be fitted with an ordinary thigh bucket. This is believed to give a good, if not better, functional result than a disarticulation.

Persistent flexion contractures at the elbow should be treated with the wedged plaster cast method as in the knee.

Slight joint deformities often markedly improve after the patient has been fitted with and has worn his prosthesis, due to the leverage exerted by it.

Chapter VI

TEMPORARY PROSTHESIS—FITTING AND INSTRUCTION IN ITS USE.

Two methods have been used more or less in the past to prepare the stump for fitting with a permanent appliance. The one heretofore mainly employed was to allow the stump to atrophy from non-use for a period of six months to a year, using types of stump "shrinkers" during this period. The other and proper method is that of fitting the stump early with some type of temporary prosthesis as nearly as possible like the permanent appliance and thereby obtaining an early physiological shrinkage along with a development of the muscle of the stump required in the use of the appliance.

To fit an appliance to a boggy, tender "green" stump, and to make the necessary adjustment to it so that it will continue to fit such a rapidly changing stump, requires the personal contact of the patient and the appliance maker. The changes in the stump are usually most marked during the first three weeks following fitting, but continue for the next four to six months. The cost of such a method where the permanent type of artificial appliance is used in civil life would be almost prohibitive. This is most probably why the shrinkage atrophy method of dis-use has been used. It is imperative, however, that the stumps be fitted as soon as the condition of the soft parts will allow if a maximum of efficiency from the stump is to be obtained.

Early fitting allows the amputé to walk without other support than that afforded by a cane and lessens the period of his incapacity for work.

Lower Extremity.—In using the artificial leg the stump or its adjacent parts are called upon to perform new and abnormal functions, i. e., weight-bearing as well as locomotion.

The weight borne in the leg stump is distributed as follows: Cone-bearing (lateral or surface bearing); bony prominence bearing (head of tibia, tuberosity of tibia, fibula below the head); partial thigh surface bearing (thigh cuff); and in certain cases, partial end bearing.

In the finished appliance, the stump is encased in a solid shell which is moulded or carved to fit the stump, so that all the bearing points and surfaces are used to a variable degree. Cone and bony prominence bearing with partial thigh bearing (thigh cuff) is used in all leg stumps. Pressure atrophy is rapid and marked as the muscle of the stump never again functions as muscle and frequent remoulding of the socket is necessary. Atrophy in the thigh due to the thigh cuff is slow but certain, and distinctly objectionable. Partial end-bearing diminishes this atrophy.

Thigh stump may be (1) end and cone (lateral or surface) bearing; (2) bony prominence (ischial tuberosity) and cone bearing. The muscles of the thigh continue to function as muscles and pressure atrophy therefore is not as marked or as rapid as in the leg.

The end-bearing stump is the ideal in the thigh and when attained should be so fitted that all the body weight is thrown on its end and lateral surfaces, none being taken on the tuberosity of the ischium.

The ischial and cone-bearing stump is the most frequent type. The amputé sits on the top of the thigh bucket with the tuberosity of his ischium and the bucket is moulded or cut out to fit the stump, affording cone bearing. The stump proper takes some of the weight by virtue of the lateral bearing, but its chief function is that of a lever.

It is hardly necessary to state that an ideal provisional appliance should possess similar mechanical features as those found in the permanent appliance. The sockets or buckets should be of solid material, accurately fitted and as mechanically perfect as the permanent one. A provisional appliance which merely shrinks the stump but does not develop the weight-bearing points and surfaces which will be called upon to function in the permanent appliance is not an efficient provisional appliance. It must be comparatively cheap, easily adjusted to fit various types of stump and readjustable so as to correct for shrinkage as it occurs.

The American permanent artificial leg has long been admitted as the best, but up until well after our entry into the war, no cheap, satisfactory temporary prosthesis had been devised. After much hard work, experimentation, etc., by those in charge of the work in the Surgeon General's Office, and at the various amputation centers with the assistance of the American artificial limb makers, a highly satisfactory temporary prosthesis made of fibre was developed. A description of this appliance will follow.

Before the adoption of a provisional prosthesis, temporary plaster buckets were made fitting the individual stump, the weight being carried on a peg as in the plaster pylon or the bucket was secured to a metal set-up, provided with a knee and ankle motion and a foot attached. This method was used extensively by our Allies as a means of early fitting. The plaster pylon has its advantage of being easily made, its construction is cheap and simple and if properly constructed, distributes the weight equally over the bony prominences, laterally on the soft parts and also on the stump end. It should always be used when the temporary fibre prosthesis cannot be obtained. Its disadvantages are its excessive weight, its bulky, awkward appearance, its lack of æsthetic requirements demanded by the amputé, and its lack of similar mechanical features found in the per-

manent appliance. This type of appliance cannot be put in quantity production and is short lived.

A description of the plaster pylon follows: A type of this fitting is exceedingly valuable in the early fitting of a double high thigh amputation to accustom the amputé to balance himself on short appliances and at the same time obtain shrinkage of soft parts, accustom bony points to weight bearing and to exercise the muscles necessary for locomotion.

The provisional artificial leg adopted by the Army and considered the best is constructed of materials of the finest quality on account of the rough usage it must withstand. The thigh and shin pieces are made of fibre, the grey machine type being best, finished in its natural color. Therefore it will not be as easily scratched when altered or worn as those coated with the usual flesh colored enamel. It has knee, ankle and toe motion as has the permanent type. The knee block and foot piece are made of willow and are not covered with rawhide. The metal parts used in the knee and ankle joints are the same as those used in the permanent appliance.

The thigh sockets are anatomically shaped with the ischial seat well shaped and broadened with a well-fitted flange of strap leather glued to the fibre (Figure 27). They are moulded from one piece of fibre, overlapping well behind, joining in a seam which is secured with copper rivets. The crease inside the bucket is obliterated by a piece of properly cut leather running its length and glued into place. The thigh bucket fits snugly around the knee block and is secured in position with wood screws. A moulded leather cuff is fitted over the upper edge of the bucket and extends downward within making it complete for fitting. The shin piece is secured to the knee bolt which runs through the knee block, by metal side strips which are held fast by metal screws.

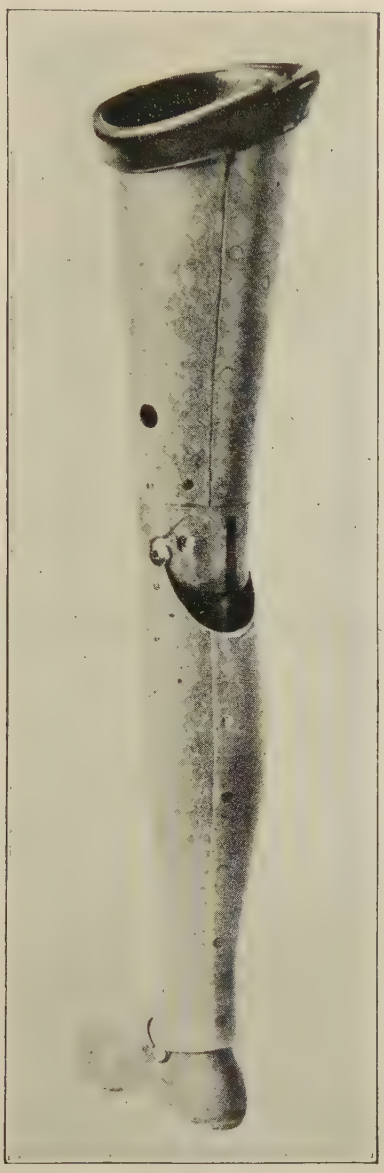


FIG. 27.—The temporary fiber prosthesis, ischial bearing without suspenders for thigh amputation. Note well moulded ischial seat, removable copper rivets securing seam in fiber of thigh bucket and screws attaching bucket to wooden knee block. The shin piece is detached from the side bars of the knee bolt by removal of three metal screws on each side. It is then cut down with a saw to the desired height. (Mr. Kuly.)

The ankle joint is of the cordless type connecting the shin piece to the foot, consisting of a "U" bolt and steel springs.

These legs can be made in quantity production and are carried in stock, rights and lefts, and in a series of sizes to fit all stumps, varying by an inch for stumps from eighteen to twenty-five inches in circumference. An average length is usually required, a long or short special is at times needed. Each stock leg is individually fitted and re-adjusted as the stump changes form. The copper rivets are removed from behind and the thigh bucket made larger or smaller. The thigh bucket is removed from the knee block and sawed off if it is too long, or raised higher on the block if too short. The length of the leg below the knee is made equal to the normal leg by removing the side straps from the shin piece, cutting it down to the proper length and replacing them. The foot is shaped as indicated to fit the size shoe the patient wears. One prosthesis only is needed to shrink the stump. The bucket is altered from time to time as indicated by the size of the stump.

In thigh stumps of four inches or less, or where the stump is large and flabby, an accurately fitted pelvic band of metal and leather is necessary, connected to the thigh bucket with a metal bar, having a one-way hinge opposite the hip, allowing flexion only. This keeps the leg from slipping off the stump when the patient sits down, makes the stump more secure when walking and lessens the rotation of the stump on the leg.

The below knee set-up or leg consists of a fibre shin piece, ankle and foot as in the thigh and the side bars and the thigh cuff (Figure 28). They are carried in stock as rights and lefts and to fit stumps with a circumference of from twelve to sixteen inches. They may be shortened by sawing off the top and adjusted by removing the copper rivets behind and made larger or smaller as indicated.

After the set-up has been adjusted as to height and circumference, the side bars are secured and the thigh cuff attached.

A plaster or leather socket is made, fitting each individual stump and is set into the fibre set-up, into which it should fit snugly, being supported around its top with a flange or shoulder of plaster or leather.

The plaster socket is made using the ordinary plaster bandage and is applied in practically the same manner as a cast. A piece of stockinette is pulled and held tightly over the stump end and up over the knee with the leg in extension. Plaster bandages are then applied extending from below the stump end up over the knee, care being taken not to pull it too tightly as this will make the inner surface of the cast rough and irregular. Before the plaster is applied, small bits of felt are cut and placed over the bony prominences as the head of the fibula and tubercles of the tibia, where pressure must be lessened and a fairly heavy cast is made. The flange which will bear the weight of the cast on the upper margin if the set-up is formed by making the cast one-quarter of an inch thicker at a selected point, running circularly around and at a right angle to its long diameter. For the average stump, two bandages are applied; the flange or shoulder is made with the third; and a fourth bandage is used to cover the whole cast and complete it.

After the plaster has set and while not yet quite dry, it is removed and cut out in front to relieve any pressure on the patella, posteriorly so that the leg can be flexed on the thigh without pinching the tissue in the popliteal space. Laterally the plaster is allowed to extend upward forming "ears," thus giving additional support for the lateral surface of the knee. Plaster sockets are easily constructed but are short lived.

The leather socket is much more durable and should be furnished only after the stump requires its first and second re-fitting following

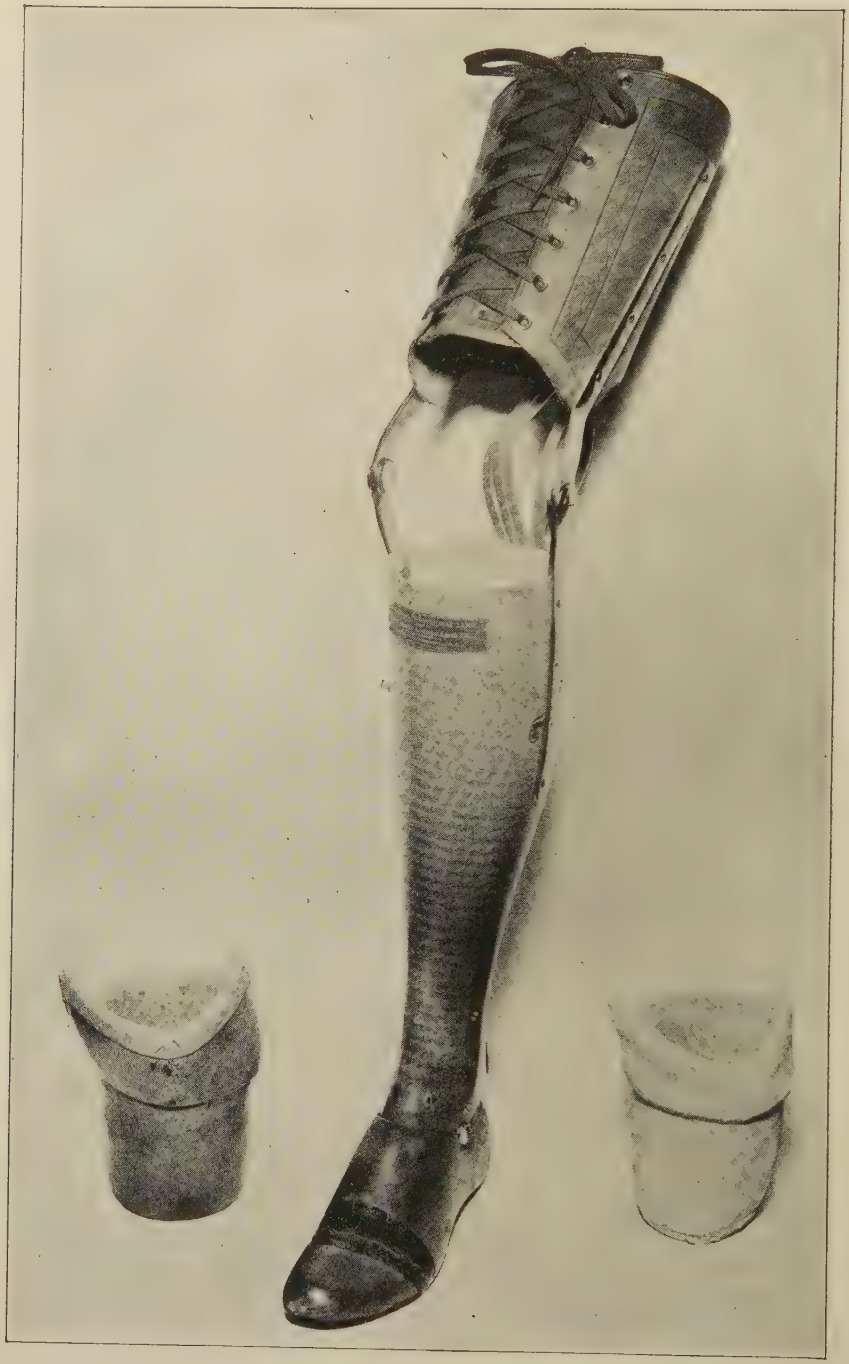


FIG. 28.—The temporary fiber prosthesis with side bars and thigh cuff. The side bars are adjustable by removal of screws. The set-up may be shortened to proper height and made larger or smaller to fit the bucket by removal of the copper rivets posteriorly as in the thigh prosthesis. At the left is a leather bucket moulded to fit the individual stump and on the right a plaster bucket fitting the same stump.

shrinkage. A plaster cast is made of the stump and this is poured full of plaster, making a mould. When the mould hardens, the cast is removed and any bony prominences which should be relieved of pressure are marked. Small pieces of leather or felt are attached over these. Three thicknesses of strap leather are moulded over this plaster model, each layer being glued together, the seam falling posteriorly and is sewed together with heavy wax ends. The outer layer extends far enough down only to make the shoulder or flange. The top is shaped up as was the plaster socket, cutting out in front for the patella, behind the knee to allow free flexion, and rounding off the "ears" laterally. The finished bucket is about one-quarter of an inch thick and is very durable. When refitting is necessary, due to shrinkage of the stump, a leather lining is inserted or the posterior seam is re-opened, leather cut away and re-sutured.

The end-bearing (thigh) leg (Figure 33A).—The end-bearing stump of the lower third of the thigh requires a different weight-bearing leg, the weight being taken on the end of the stump and laterally on the soft parts. The type adopted and made in the Army prosthetic shops is constructed as follows: a cast is made of the whole stump leg from the stump end to the groin. A mould of plaster is poured. When the mould has dried and been removed, a piece of heavy sole leather is wet and moulded to fit it snugly laterally and over its end. The leather having been cut to fit, the end is sewed together with heavy wax ends over it and extending upward on the anterior surface for some three or four inches. From this point to the top of the bucket, the leather is cut back, metal eyelets are inserted, a tongue sewed in and a rawhide lace introduced. The upper part of the bucket can therefore be laced at all times with the snugness desired. Circular felt pads on which the stump end rests are placed in the end of the bucket in numbers as indicated. This leather bucket is secured to the ordinary fibre shin piece by means of two

A B

FIG. 33

(A) End bearing stump of lower third of thigh showing temporary prosthesis with shoulder straps. The thigh bucket is made of moulded sole leather, the shin, ankle and foot is an ordinary temporary fiber prosthesis. The two lateral side bars, with one way joints are attached to the bucket with copper rivets.

(B) The below knee temporary fiber prosthesis with moulded leather socket fitted.

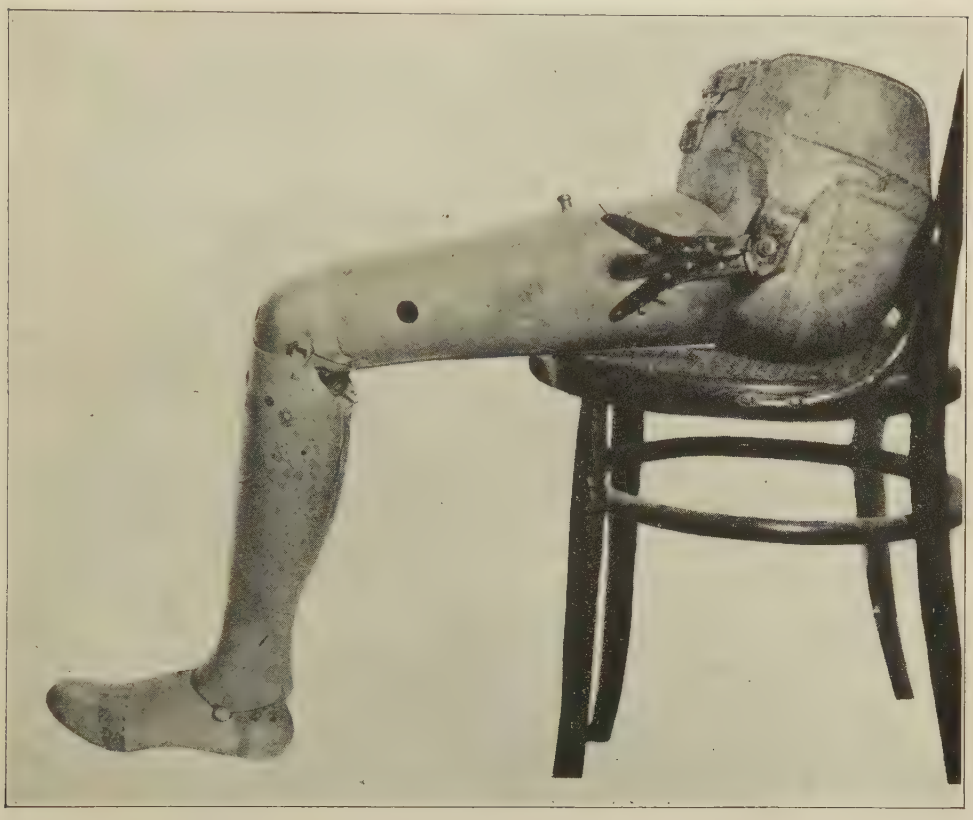


FIG. 29.—Prosthesis for hip joint disarticulation developed at the Walter Reed General Hospital, with automatic hip and knee lock showing release levers. The hip locks both externally and internally overcoming the weakness in most prosthesis of this type. The temporary fiber prosthesis has been used in the construction of this appliance.

lateral side bars with joints at the knee, allowing flexion only to the normal angle, the latter being reinforced by rawhide thongs extending between the shin piece and the leather bucket behind the knee.

Hip joint disarticulation (Figure 29).—A temporary prosthesis for this amputation is not essential as comparatively little shrinkage occurs, the whole weight being borne on the tuberosity of the ischium. A brief description, however, of the prosthesis developed by Mr. Segarm, a leg fitter at Walter Reed General Hospital, is given as it has proven the lightest in weight, the most durable and the best fitting type I have seen. It also completes the Army's armamentarium for all types of leg prosthesis.

A plaster cast of the disarticulation including the buttock extending upward to the crest of the ilium and medially just short of the median line of the body is made. A plaster mould is made and on this is moulded a leather socket incorporated in which is a steel frame. The socket is held in place by one shoulder and one body strap. The steel frame extends downward and is attached to the stock fibre ischial bearing prosthesis. There is an external and internal lock, operated by one lever, the joint being located on an equal level with the opposite hip joint. On standing the joint locks automatically and is released by the pressure of the amputé's hand on the handle of the lever on the upper outer aspect of his thigh when he desires to sit down. A knee lock has also been added to the stock prosthesis. By pulling a lever on the anterior surface of the thigh, the patient can lock or unlock the knee at will. This is easily accomplished through his clothing and these levers do not show.

The plaster leg.—Where the equipment of an orthopedic shop is not elaborate or there is no experienced leg fitter available, the plaster leg can be used to a great advantage.

A description of this leg is as follows (Figure 30): Steel uprights with a joint at the knee and an extension for the thigh cuff

FIG. 30.—An easily constructed below knee prosthesis. A plaster socket applied to the stump in same manner as a plaster cast is riveted to a stock set up. The metal side bars are constructed of two pieces so that they can be lengthened or shortened and fixed with rivets. A wooden peg may be substituted for the foot. The strap running from heel to instep of foot over ankle block is made of heavy elastic webbing controlling ankle motion.

are made of proper length. A foot with or without, preferably with, an ankle joint is attached or a round peg end may be fashioned. The thigh cuff is made of leather, lacing in front and after the steel uprights have been properly aligned and bent to fit, it is riveted in place. The success depends largely upon the plaster socket. In fact, a less elaborate set-up to hold the socket may be made from wood. The socket is made more or less as the plaster socket for the fibre leg. A piece of stockinette with one end closed is pulled over the stump end, the upper end extending well above the knee, on which traction is made by the patient to displace soft parts upward with the leg in extension. A second piece of stockinette is applied over the first, leaving the lower end open and extended blow the stump end. Plaster bandages are applied, care being taken not to draw them too tightly causing compression rings. As the cast is applied, it should be moulded upward to displace soft parts, and fitted well about the bony points where pressure is to be relieved and weight borne. Here the cast should be reinforced. The cast should extend well below the stump and above the patella. Before the cast is completed, and after the inner layer has begun to set, two strips of thin sheet iron are bent and placed on its sides where the rivets will subsequently be placed. The cast is then completed, incorporating them. The cast is then trimmed away above, the outer and inner sides are extended to the middle of the patella, in front it is cut away under the patella and posteriorly to allow complete flexion. After the excess is cut away, the remainder must be moulded with the fingers. The outer layer of the stockinette at both the upper and lower ends is turned out over the plaster and incorporated in it. The plaster should dry thoroughly before any riveting is done. The shoulder strap and knee check are riveted to the cast and it is then riveted to the set-up in the proper position.

The socket for the thigh stump is made in a similar manner,

FIG. 31.—TWO TYPES OF PLASTER PYLONS.

(A) Has two rigid uprights of wood, rivetted to the plaster bucket which has incorporated in it two strips of metal to hold the rivets. The wooden uprights are secured by screws below to a wooden "peg." The appliance is shellacked after its construction is completed, which lengthens its life.

(B) This type of pylon is mounted on two lateral iron bars which are secured to a block at the knee. The peg is locked in extension at the knee block when walking and unlocks when the ampute sits down. The suspenders are riveted to the upper margins of the plaster buckets in front and behind.

especial care being taken in moulding the seat for the tuberosity of the ischium (Figure 31). If end bearing in either case is desired, the stockinette should be carefully fitted to the stump end so there will be no wrinkling and the end incorporated in plaster.

The cast may be mounted on the shin piece of an artificial leg, or on two lateral pieces of wood with their end coming to a point, forming a "peg" at the ground with no knee motion. The wooden or metal side bars may be fastened to a block of wood at the knee and a joint made so that the leg may be flexed when the patient sits down or the ordinary peg leg may be attached.

Fitting (Figure 33).—As stated, a primary amputation healing by first intention is ready for and should be fitted not later than six weeks after operation. If healing is delayed in any case, as frequently occurs in the repair of an infected stump, guillotine or otherwise, a fitting should not be done until healing is complete and the suture lines secure. There is always some tension on suture lines and the tendency to force "the bone end through the soft parts" due to the lateral surface bearing (conical) of the stump. The patient should not attempt to wear the leg continually from the time he is fitted for the first ten days even if it "doesn't hurt." The skin will chafe, the bony weight-bearing points become bruised, contused and sore and the stump is soon incapacitated. The new work thrown on these parts must be gradual until they become accustomed to it and should be carried out under competent instructors. When the leg is removed, the stump should be tightly bandaged with a white flannel or elastic bandage after a cold bath has been given it or swelling will occur and the leg be "too small" the following day.

The best possible stump surgically can be easily ruined if it is not properly fitted. The bucket of the prosthesis that properly fits the stump and that is properly aligned is the best leg that can be obtained. In the thigh stump the bucket should fit snugly the lateral

surfaces of the stump, the ischial seat must conform to take the body weight on the tuberosity of the ischium. Pressure must be relieved from the perineum and the upper end of the bucket must be snug or the seat will be insecure. The patient should be able to wear comfortably one thin or medium white woolen stump sock when originally fitted.

The below-knee stump likewise should wear one long medium weight stump sock, extending up the thigh under the thigh cuff. The weight must be taken off the head of the fibula, and too much must not be thrown on the tubercle or long sharp crest of the tibia. The socket at all times must be longer than the stump and exert equal pressure over all of its lateral surfaces.

As shrinkage occurs, additional stump socks are worn, otherwise the stump sinks in the bucket and weight is no longer borne on the proper bearing surface.

Stumps, prosthesis, and the way the patient wears them must be frequently inspected and the numerous minor alterations and adjustments made. When the patient requires more than three stump socks, if in the thigh, the bucket must be made smaller or in the below-knee stump, a leather lining must be placed in the socket or a new one made.

In a surgically good stump, properly fitted, the patient is ready to leave the hospital, walking only with the aid of a stick on rough ground, at the end of from four to six weeks. During this period his stump will have shrunk enough to require one and probably two adjustments to his bucket. Prior to his discharge, his bucket should fit him so that he is able to wear only one stump sock.

FIG. 32.—Short plaster pylon with "elephant feet" used in teaching double amputations of the thigh how to balance and walk. At the same time they toughen weight bearing points, strengthen muscle power and cause shrinkage of the stump.

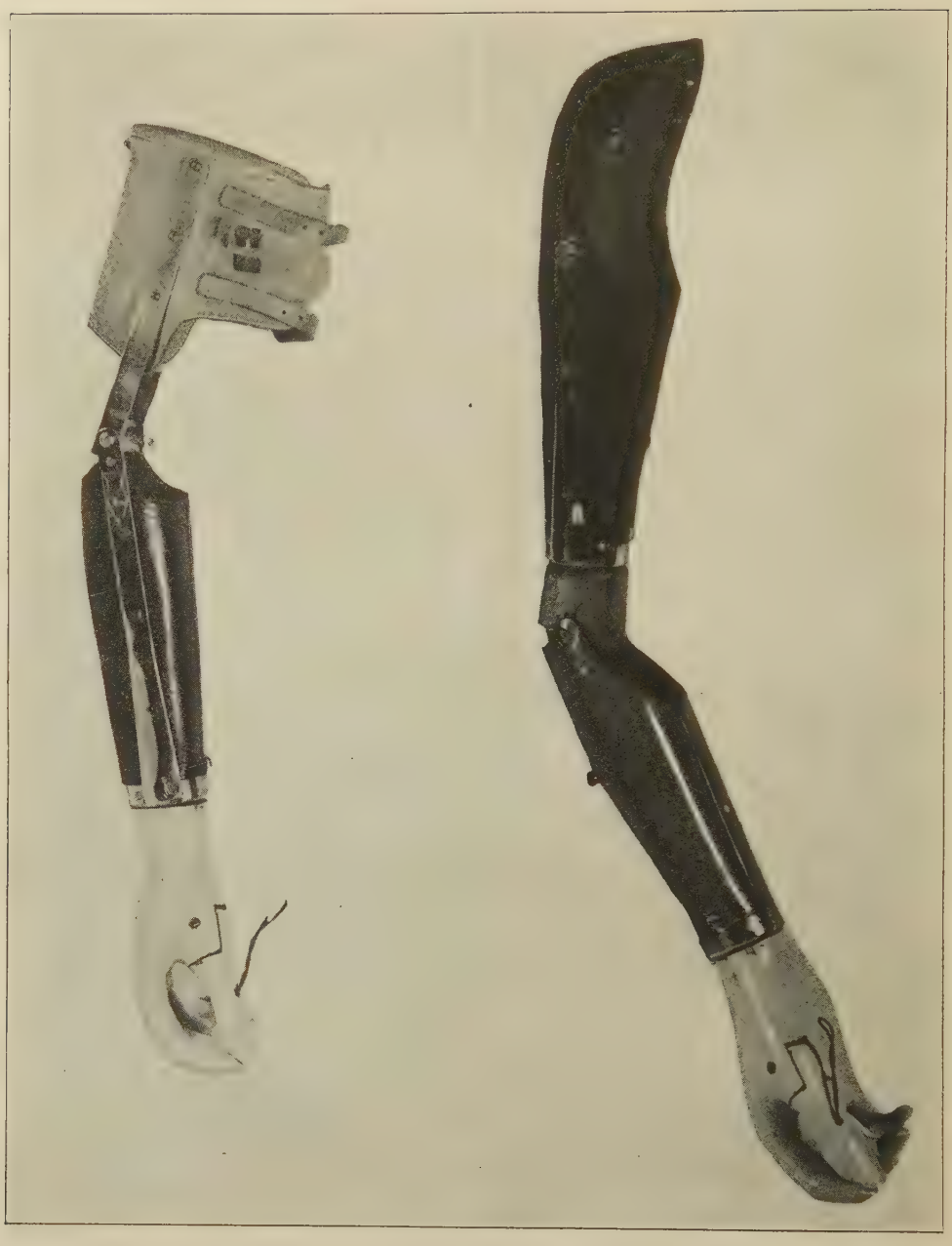
Instruction in the Use of the Prosthesis

Where a large number of cases are handled together, as was the case after the present war, definite routine daily instructions should be given, under competent instructors, in classes of not more than twenty men to the class.

When practicable, the men were divided into two sections—thigh and leg cases. As soon as a man was fitted, he was ordered to report to class. The above classes were re-divided into beginners and those who had learned how to handle themselves. The beginner graduated into the advanced class as soon as proficient. Special individual instruction was given to double amputations and backward cases (Figure 32). The period of instruction was an hour daily as a minimum. Crutches were taken away when the patient was using his leg and two canes when necessary were allowed or low parallel bars were used for support. If the crutch is used too much weight is taken off the leg and the stump pulls out of the bucket or socket with each step.

Patients were first instructed what motions of the stump were essential in locomotion, how to lock the knee and swing the leg. Later they were marched around the room in columns, taught how to turn and balance, games were introduced, various setting up exercises were given so that the patient would gain confidence, learn what he could do and at the same time get much needed exercise. They were taught how to balance and swing the leg by walking on a narrow plank raised six inches from the floor and how to go up and down stairs.

Without exercises of this nature the large majority of men have a tendency to stick their artificial leg under the bed, use their crutches that they are accustomed to and put the leg on only for inspection. When the amputé has been made to see that he can



A B

FIG. 34.

(A) The temporary (or permanent) forearm prosthesis with hand attached. The leather cuff is moulded to fit the stump. The metal side bars are continuous with the end piece in which the hand is locked and are made of nickelled steel. The shoulder strap for retaining the prosthesis and the thong running up from the thumb, which crosses the back and is attached to the webbing strap of the opposite shoulder is not shown.

(B) Arm prosthesis. The leather bucket is moulded to fit the stump and shoulder and is riveted to two lateral nickelled steel side bars attached to a lock end piece which holds the forearm prosthesis. The release bar holding the elbow flexed at any desired angle is seen on the posterior surface of the forearm piece. The forearm piece is constructed of fiber—shoulder straps, etc., are not shown.

wear the leg without discomfort, he gets confidence in it, and knows how to use it, he never goes back to crutches unless he has to. There are two kinds of amputés—those who wear their legs and those who go about on crutches—there is no middle ground. Unless the amputé learns early how to use his appliance and likes it, he might as well have none—he will use crutches and excuses the rest of his life.

This routine must be carried out in each individual case.

The upper extremity (Figure 34).—The temporary forearm prosthesis consists of an artificial hand, made of wood which has been enameled only. The fingers are in a semi-flexed position. There is a joint at the base of the thumb with a spring which keeps the thumb closed and in contact with the index finger. A rawhide thong or cord is attached to the thumb which runs along the outside of the forearm and around and across the back where it is attached to a webbing strap which is secured around the opposite shoulder. The thumb is opened by the patient lifting his opposite shoulder. The hand is useful only as a carrier or holder of objects. The split hook of the Dorrance type which is operated in the manner described for the thumb is the most useful all around working tool and is interchangeable with the hand. It is surprising what can be done with this tool by a properly instructed amputé (Figure 35).

The forearm bucket is made of leather moulded to fit the stump and sewed together with wax ends. It is attached to a stock set-up of nickel plated steel which consists of an end piece into which the hand or hook is locked and two lateral side bars. The hand locks automatically when pushed in position and is released by pressure on a small relief bar at the wrist. The side bars may extend only to the elbow in which case the forearm bucket is secured to the arm cuff by means of two lateral leather straps. The bars are extended to the upper third of the arm with a joint at the elbow in amputations above the middle third of the forearm and the arm cuff is riveted to them.

A B

FIG. 35.—WORKING APPLIANCES FOR THE PROSTHESIS OF THE UPPER EXTREMITY, INTERCHANGEABLE WITH THE COSMETIC HAND.

(A) The split hook of the Dorrance type is considered the most satisfactory and useful all around working appliance made. It is opened by lifting the opposite shoulder through the thong that ordinarily operates the thumb and is secured to the eyelet in the arm extending from one of the hooks.

(B) The simpler open hook type of appliance for general work.

The arm cuff is made of leather and is made fast around the arm by leather straps. It supports the forearm fitted as indicated and is in turn kept from slipping off by means of two leather straps and buckles which secure it to a leather shoulder cap. This cap is held in position by a webbing strap which passes around the back under the opposite arm and across the chest, being made fast by a buckle in front.

The temporary arm prosthesis has the same type hand or hook, operated in the same manner as on the forearm. The forearm part is made of the same type fibre as the artificial leg and has a similar metal end piece and lock at the wrist as the forearm set-up. It has an elbow joint which allows the full range of motion of the normal joint and will automatically lock at any angle. The lock release is about four inches below the joint on the posterior surface of the forearm and can be operated through the coat sleeve. The upper end of the artificial forearm appliance above the joint is made of wood, corresponding to the knee block in the thigh prosthesis. It has protruding upward a small metal peg which locks into the metal end of the arm set-up. This lock has a release similar to the one at the wrist. The metal set-up for the arm stump is made of nickle plated steel and has a metal end piece receiving the forearm attachments and two lateral bars which are riveted to the arm bucket.

The arm bucket is made of leather, moulded to fit the arm stump and the shoulder, being cut out well internally to allow room for the axillary folds of soft parts. It is laced to the leather shoulder cap which is held in place by a webbing strap in the same manner as the forearm prosthesis.

The shrinkage that occurs in the stumps of the upper extremity is much less than in the lower. Fewer re-fittings are necessary and are not as difficult. Stump socks are provided as in the lower extremity. Early instruction in the use of the appliance is essential.

The patient usually has learned to do all his work with one hand and considers the appliance a nuisance or wears it only to fill out his sleeve.

The work that can be done with the split hook appliance is remarkable and the patient should early be shown how to do this work or this appliance is useless to him. Patients were required to do a certain number of hours work daily with the appliance in the woodshops or on the farms and gardens.

All appliances whether temporary or permanent, for the upper or lower extremities, should be made of the best material, as light as stability will allow and as simple and with as few parts to get out of order as possible. The more complicated the appliance with levers, springs and moving parts, the more useless it is.

The simplest appliance that properly fits the individual stump, taking the weight on the proper weight-bearing points, with the proper alignment, is the best.